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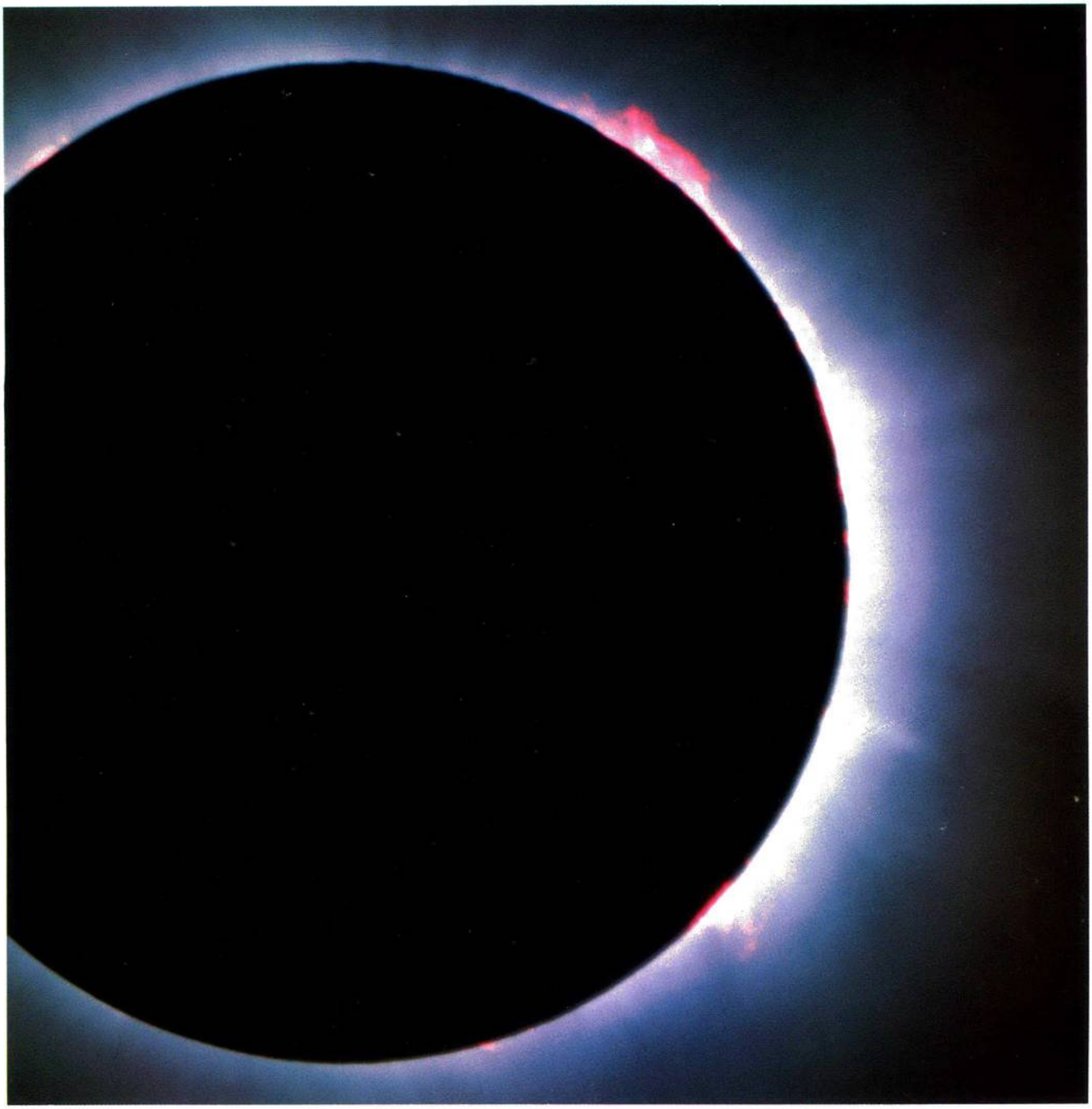

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Meade 10″ 2120/Model 56H. Shown with optional Digital Readout System.

Background photo: The Lagoon Nebula (M8). A 20-minute exposure with the Meade 8″ 2080/Model 56.

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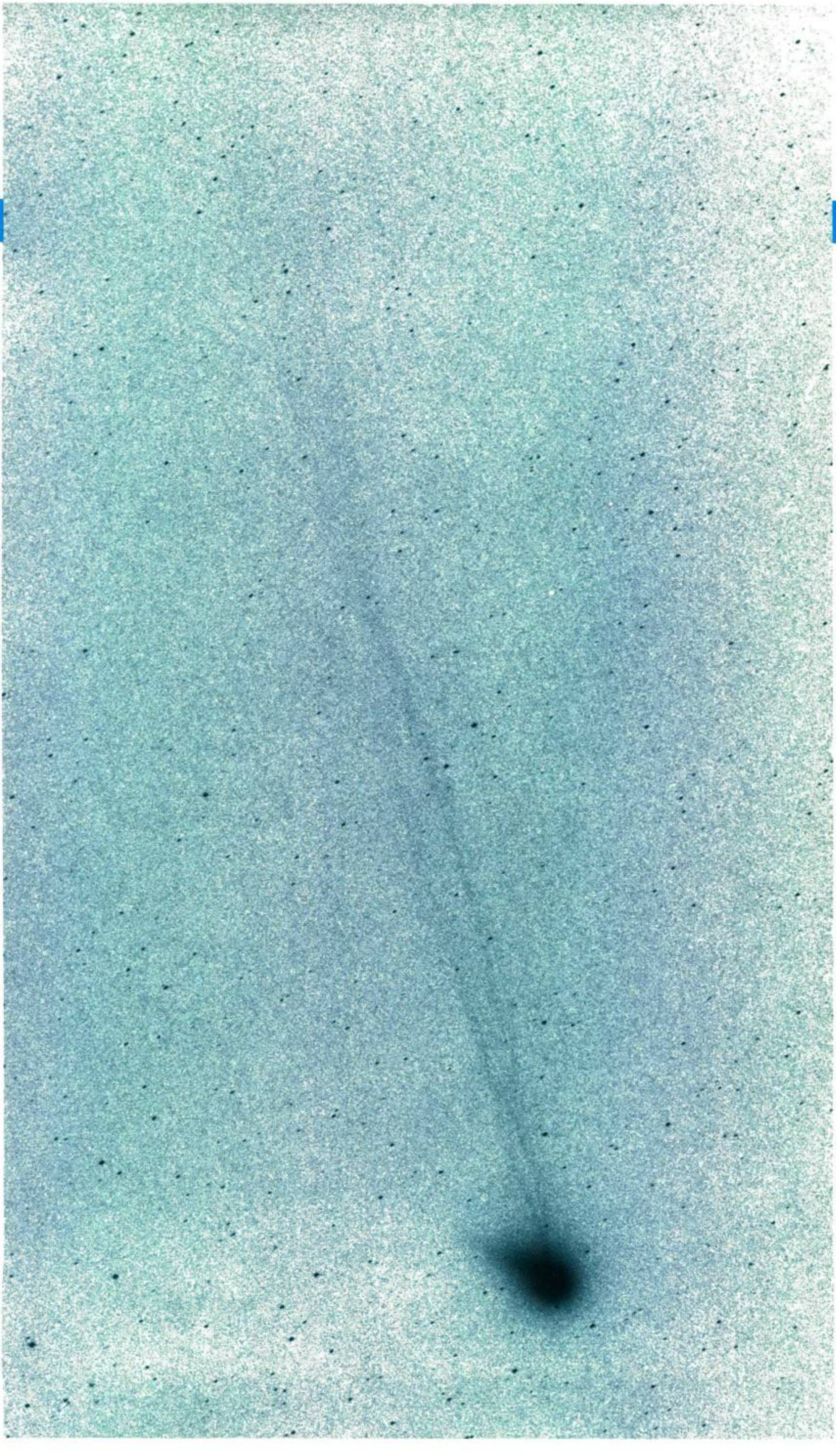
ON THE COVER: You can see prominences and the corona, the tenuous outer atmosphere of the Sun, during a total solar eclipse. Observers will behold a similar spectacle during next July's eclipse. (See page 68.) Photo by Ken Hilgendorf.



COMET AUSTIN'S long, straight ion tail was captured in this photo taken by the European Southern *Observatory's Schmidt telescope* at La Serena, Chile, in February. The short stubby tail consists of dust particles fanning out from the nucleus.

ASTRONOMY®

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Behind the Scenes

WHAT'S NEW FOR JULY?

Ninety-five percent of ASTRONOMY's readers liked our major design overhaul two years ago. This July we're doing a bit of "fine tuning" to make ASTRONOMY even more the magazine you want it to be.

You told us you like our Letters department, so we've expanded it to twice its old size. Through the Letters column your voice becomes a part of ASTRONOMY in an on-going debate of views with other readers like yourself — or *unlike* yourself. Then we took another hint from our readers and consolidated the old Viewpoint and Forum columns into a new front-of-the-book department called Viewpoints.

Because you asked us to put fewer advertisements between our feature stories, we've done it. Our art department redesigned the entire feature article section and added more color pages, too. Then they suggested that more distinctive department headings would help you navigate our pages more easily, and those we've added, also.

In this issue we're introducing an important new reader service: ASTRONOMY's New Products department. As astronomy has grown, many more new and interesting products and services have come on the market. In your letters and phone calls, you've told us you want to learn about these new products and services as soon as they appear. That's what ASTRONOMY's New Products department is all about.

To get New Products started, we asked every company that makes or supplies astronomical equipment, products, or services to help us keep you informed. From now on, when companies introduce new equipment for amateur astronomy, you'll read about them first in ASTRONOMY's New Products department. It begins on page 96.

But the service doesn't stop there. Each month we'll obtain production samples of the products we judge to be the best and most interesting. We'll test them and then concisely report our results to you — good or bad — in Product Reviews, which begins on page 92 in this issue. And of course whenever a major new piece of equipment is introduced we'll feature an in-depth review as soon as we can thoroughly evaluate the product and its performance.

These changes and others to come in ASTRONOMY are made for you, our readership. We value you and we value your ideas. Whether you're one of the many who has answered our monthly magazine survey questionnaire or someone who sent a letter full of suggestions, we appreciate your input. Through you, we're making ASTRONOMY the best there is.

Clear Skies,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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Letters

In Search of the $200 Telescope

People who think they are going to purchase a worthwhile telescope for $200 must have just stepped out of *Back to the Future*. At present I have a Powerstar II and will advance to the Ultima 11 as soon as my dealer has one available, but fifteen years ago the only way I could afford a telescope was to make my own. I spent endless hours grinding an 8-inch mirror and reading Newton's *Opticks*.

In those days the lumber, pipes, and optics cost $200. How can a telescope manufacturer produce a worthwhile instrument for that amount today? A quality scope can still be home-built for a reasonably small amount, but let's not be nostalgically unrealistic. — *Christian Foy, Guilford, Connecticut*

I've followed the discussion in your Letters column about the affordability of telescopes with great interest. I found myself in the usual predicament of not being able to afford a really good telescope because of the high cost of living. Nevertheless, I regularly observe with an 8-inch SCT, a 13.1-inch Dobsonian, and a pair of 11x80 binoculars.

Am I bragging? No! I joined my local astronomy club, which provides access to telescopes. The membership cost is small enough for virtually any budget. — *Leo White, Philadelphia, Pennsylvania*

Amateur astronomy is little by little turning into a rich man's hobby. I'm tired of wanting to own a quality telescope and reading reviews of instruments costing $1,500 or more that are poorly made. On top of this, manufacturers artificially and substantially raised telescope prices across the board for the arrival of Comet Halley. Will the same happen with Comet Austin?

When I was young and first interested in astronomy, my dream was to own a fine telescope. Thanks to the greed of manufacturers and dealers, I may never attain that dream. — *John J. Kubenski, Jamestown, North Dakota*

I can't figure out what the fuss is about. In the same issue that contains fearful letters about the high cost of telescopes, there are advertisements for two reasonably priced telescopes. Coulter Optical offers an 8-inch Odyssey reflector for $239.50 and Adorama advertised Edmund Scientific's Astroscan 2001 4.25-inch reflector for $279.95. These as well as other comparably priced scopes are advertised

Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

- George N. Storm, California

Photo by Jim Riffle

Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  1) Apo-refractor - basic design
  2) Tele Vue reputation
  3) Dealer owns same model
  U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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"On the Moon and Jupiter, the Odyssey 8 showed as much detail as several 8" Schmidt-Cassegrains nearby."
David McGough, Millington, N.J.

"It is worth twice what I paid, but please don't raise the price. I want to get my son one in a few years."
Tom Johnston, Boulder, Colo.

10.1 inch $345.00

"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
Lee Jchnson, Coquitlam, B.C. Canada

13.1 inch $575.00

"In amateur astronomy for over 35 years and I have seen my share of all kinds of telescopes, good and bad. To say the least, the Odyssey 1 outperforms anything that I have seen!!"
Richard Ziegler, Maumee, Ohio

"There is not another telescope of equal size in our club that can touch the clear image and ease of operation that Odyssey 1 provides."
Mark Davenport, Pinellas Park, Fla.

17.5 inch $1150.00

"I've only had a chance to view once so far, but am thoroughly thrilled with it. Viewing from a (Santa Barbara, Ca.) residential front yard, the Orion Nebula was indeed a treat – reddish tinges on the predominating green, with many subtle wisps and lanes very clear. The Andromeda Galaxy was surprisingly bright, as was its companion." David Broad, Santa Barbara, Ca.

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A low-cost alternative is to make a "copyscope" from a simple copier lens, a good eyepiece, a photo tripod, and a few other bits and pieces. I've made copyscopes that deliver satisfying views for as little as $75. — *Paul D. Webb, Columbia, South Carolina*

Testing the Equipment

I am happy to see your magazine doing more product reviews. The review you did on the Meade 2120/LX6 (December 1989) provided readers with a service that one can't place too high a value on. In an age when you can spend thousands of dollars and still get a piece of mediocre equipment, it's nice to weigh the information in the test reports rather than play Russian roulette through the mails. — *Gene E. Townsend, New York, New York*

I appreciate the positive product review of my equatorial platforms ("ASTRONOMY Tests a Dobsonian Equatorial Platform," April 1990), but it should be noted that the platforms are far more accurate than you reported. If the synchronous motor's output speed is "fine tuned" with an inexpensive drive corrector, the platform will keep an object centered in a high-power field for a full hour. This also makes long, unguided exposures feasible with short focal length lenses piggybacked on the telescope.

Since the review was published I have outfitted all of the platforms with an on/off switch, a carrying handle, and a rewind crank. — *Tom Osypowski, Nevada City, California*

Lunar Prospector Prospects

The article "A Private Return to the Moon?" (AstroNews, April 1990) contains a number of omissions and errors. First, the Lunar Prospector project is being carried out by the Space Studies Institute (SSI) of Princeton, New Jersey, and Lunar Exploration, Inc. (LEI), of Houston, Texas. These organizations have formed the Lunar Consortium, in which SSI is responsible for fund raising, publicity, and political activities, and LEI is responsible for the scientific and engineering aspects of the project.

In describing the spacecraft, the article states "there will be several antennas extending radially from the craft." The medium-gain antenna extends from the spacecraft, but the three radial extensions are instrument booms, not antennas. The Moon's gravity field will be mapped by a two-way, S-band Doppler tracking system, not a simple radio.

Finally, we have not decided how the Lunar Prospector will be launched. All options will remain open until we come to terms with one of the existing launch facilities. — *Alan Binder, LEI cochairman, Houston, Texas*

Righting a Wrong for Bausch & Lomb

Alan Dyer was wrong when he stated in his article on Schmidt-Cassegrains ("Genesis of a Legend," October 1989) that the Dynamax SCT survived in restyled form as the Bausch and Lomb 8001 until August 1988. The 8001 was entirely a Bausch and Lomb design, and bore no resemblance either mechanically or cosmetically to the Criterion-designed Dynamax.

One might assume that Dyer confused the Dynamax 8001 with the 8000, which was essentially a redesigned Dynamax. I own a Bausch and Lomb 8001 and can unhesitatingly state that it is as good as Celestron or Meade's 8-inch SCTs. — *Karl Fabian, Chicago, Illinois*

Space Missions = Space Junk

I was extremely impressed with the detailed listing of space missions for the next decade you published recently ("A New Era in Space," January 1990). I will be looking forward to all of those missions as they develop.

I am concerned, however, that these and other missions will ultimately choke Earth orbits by producing incredible amounts of orbiting debris. Are scientists and engineers working on any possible solutions to junking up near-Earth space? — *Lincoln Tritt, Arctic Village, Alaska*

Timothy Ferris Defended

I enjoy reading Jeff Kanipe's contributions to your magazine, but I take issue with his assessment of Timothy Ferris' book *Coming of Age in the Milky Way* (Astronomy Books, January 1990).

Kanipe argues that Ferris writes as a pedant, that his "distinctly erudite air...too often obscures rather than illuminates," and that the Ferris style intrudes upon the telling of the tale. Ferris wrote *Coming of Age* to create broad scientific and human contexts for the milestones in astronomical discovery, and I think he succeeded. I found his prose clear and his approach engaging. The illustrative quotations and epigrams that apparently irritated Kanipe amplified the text and added color to a subject that is often treated unimaginatively. — *Paul Baker, Madison, Wisconsin* ☐

Finally!! The ULTIMA® Series Eyepieces

► (Top right) Ultima Series Eyepieces. (Bottom left) Ultima eyepiece shown with standard eyecup.

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Each Ultima eyepiece is computer designed using the finest optical glasses. While there is no "perfect" eyepiece, each Ultima is designed to keep the following aberrations to an absolute minimum: spherical, coma, astigmatism, distortion, color, field curvature and spherical of the exit pupil.

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The Ultima Series of eyepieces is not of traditional Plössl design (nor are certain other manufacturers' eyepieces misleadingly labeled as "Plössl"). The Ultima Series are hybrid designs of 4 to 7 elements not seeking a name but rather a reputation for performance, minimization of aberrations, long eye relief and a wide field.

All Ultima eyepieces are **fully multi-coated.** This means the finest multicoating on *each* air-to-glass surface—not on one or two surfaces as is currently done on some major brands. These full multi-coatings DO enhance contrast levels.

Most eyepieces are parfocalized except where noted in the table. The wide angle units are parfocalized within their respective focal lengths.

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93350	5 mm	5	50°	1¼″	4.2 mm	yes
93351	7.5 mm	5	51°	1¼″	5.3 mm	yes
93352	12.5 mm	5	51°	1¼″	9.0 mm	yes
93353	18 mm	5	51°	1¼″	12.9 mm	yes
93354	24 mm	5	51°	1¼″	17.9 mm	yes
93349	30 mm	5	50°	1¼″	20.6 mm	yes
93355	35 mm	5	49°	1¼″	24.9 mm	no
93356	42 mm	5	36°	1¼″	31.7 mm	no
93357	15 mm-WA	7	70°	1¼″	7.2 mm	yes
93358	19 mm-WA	7	70°	1¼″	9.5 mm	yes
93359	23 mm-WA	7	69°	1¼″	9.5 mm	yes
93360	45 mm	5	50°	2″	32.1 mm	no
93361	60 mm	5	45°	2″	39.2 mm	no
93362	80 mm	4	34°	2″	50.3 mm	no

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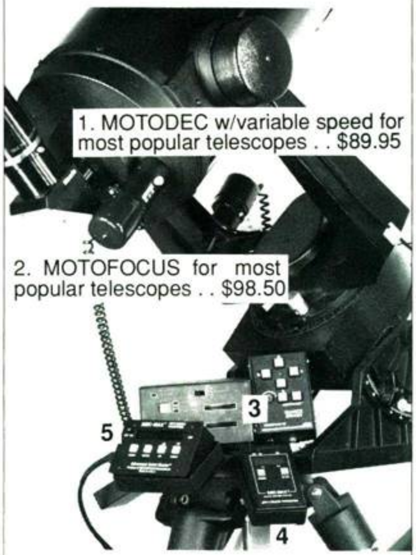
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Viewpoints

2001! A MISSION TO PLUTO

by Alan Stern
Planetary astronomer at the University of Colorado in Boulder

Six decades after its discovery, technological advances ranging from CCDs to the *Space Telescope* have begun to unlock Pluto's secrets and to unleash a surge of interest in mounting a mission to this, the last unexplored planet in the solar system. Such a mission would excite the imagination and test our post-*Voyager* scientific insight. More importantly, however, a Pluto mission promises new insights on the origin of the outer planets.

Pluto is a small world at the ragged edge of the planetary system. It orbits the Sun every 248 years on a lazy path that takes it from inside Neptune's orbit to almost twice as far out as Neptune. Pluto's orbit is more elliptical and more inclined than any of the other planets. Just last September Pluto made its closest approach to the Sun since 1741 and is now slowly receding again.

During the 1980s our understanding of Pluto was revolutionized by a series of new discoveries. Researchers found that Pluto's density is closer to that of rock than ice (an unusual occurrence in the outer solar system), that Pluto has complicated atmospheric cycles, and that its large moon Charon (discovered in 1978) forms the only true double planet in the solar system. Recent theoretical models even show that Pluto's atmosphere is likely to be spilling over onto Charon in much the same manner that gas is transferred between binary stars.

Pluto is also now known to be the only planet with an atmosphere that forms and decays each orbit, during the decades around perihelion. Further, Pluto is believed to be the only planet-sized outer solar system body that was *not* associated with a giant planet during its formation. As such, Pluto likely contains unique and essential information about conditions during the epoch of outer solar system planetary formation.

In the spirit of planetary reconnaissance for which it is famous, NASA is now studying how a modest flyby mission to Pluto could be conducted. As presently envisioned, a small spacecraft carrying cameras, spectrometers, and a plasma-science package could be launched in 2001. Engineers at JPL and NASA facilities have recently completed a first conceptual design for the Pluto spacecraft. Employing innovative design features such as a telemetry system with a low transmission rate but a high data storage capacity and fixed, body-mounted sensors, the Pluto flyby spacecraft is likely to cost only a small fraction of what recent and more complex NASA Mars, Jupiter, and Saturn orbiter missions have.

Launched on a Delta-class expendable rocket and flying a trajectory that takes advantage of gravity-slingshot maneuvers at Earth and Jupiter, the spacecraft would reach Pluto only 13.6 years after launch. This flight time is close to that of *Voyager*'s trip to Neptune, with a chance to make studies of an asteroid, Jupiter, and the heliosphere along the way. Further, this mission will arrive at Pluto at a particularly important time — while Pluto's atmosphere is undergoing its dramatic, once-every-orbit freeze-out and collapse.

This simple mission can address many important questions about Pluto that cannot otherwise be answered. It will make high-resolution maps of the surface geology and composition of Pluto and Charon. It will determine the internal structure of both bodies, search for other moons (and even rings), characterize Pluto's atmospheric structure and composition, and study its comet-like interactions with the solar wind. More importantly, the information gained from such a flyby will give us clues about the formation of Pluto and Charon, thereby opening new insights into the history of the outer solar system.

In some ways the 1989 *Voyager* encounter with Neptune's large satellite Triton, which is similar in size and density to Pluto, may have given us a glimpse of how fascinating the ninth planet may be. *Voyager* discovered that Triton is a salmon-pink and ice-blue world, 2,720 kilometers in diameter, with a cryogenic hydrocarbon atmosphere and a complex geological history. It conclusively determined that Triton's atmosphere contains both methane and nitrogen gas blowing across the surface at high speed. *Voyager* also discovered that Triton's atmosphere exhibits detached hazes, and aurorae which are excited by charged particles in Neptune's magnetosphere. After the flyby, science teams discovered active volcanic plumes rising kilometers into Tri-

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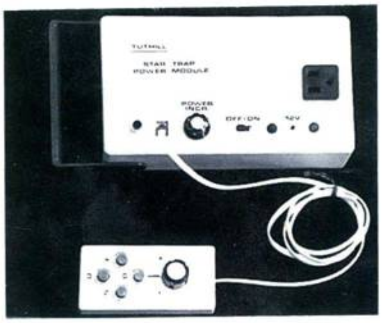

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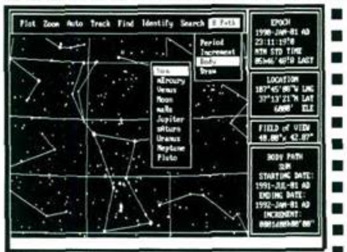

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ton's atmosphere.

Given our advance knowledge of Pluto's collapsing atmosphere and its large moon Charon, Pluto will likely offer us a kaleidoscope of planetary processes unparalleled among the icy worlds of the outer solar system.

Yet without a reconnaissance mission, it's unlikely that we will ever understand the Pluto-Charon system or reap the secrets it has to tell us about the origin of the solar system. One need only remember how wrong early ideas about Mars and Venus were, before the *Mariner* expeditions, or how enigmatic Io and Titan were before *Voyager*. Everywhere we have been we have learned that Earth-based studies, no matter how sophisticated, necessarily underestimate the richness and diversity of complex physical phenomena awaiting us. Given our long experience of misconception about planets viewed from afar, it's unlikely that Pluto can be understood without a flyby or orbiter. There is just no substitute for going there.

A Pluto flyby mission will be an Everest-like accomplishment in planetary exploration, constituting a feat of undeniable technological accomplishment and scientific achievement. A Pluto mission will also serve as an opportunity to carry the spirit of twentieth century planetary reconnaissance into the twenty-first century. NASA should be a part of it.

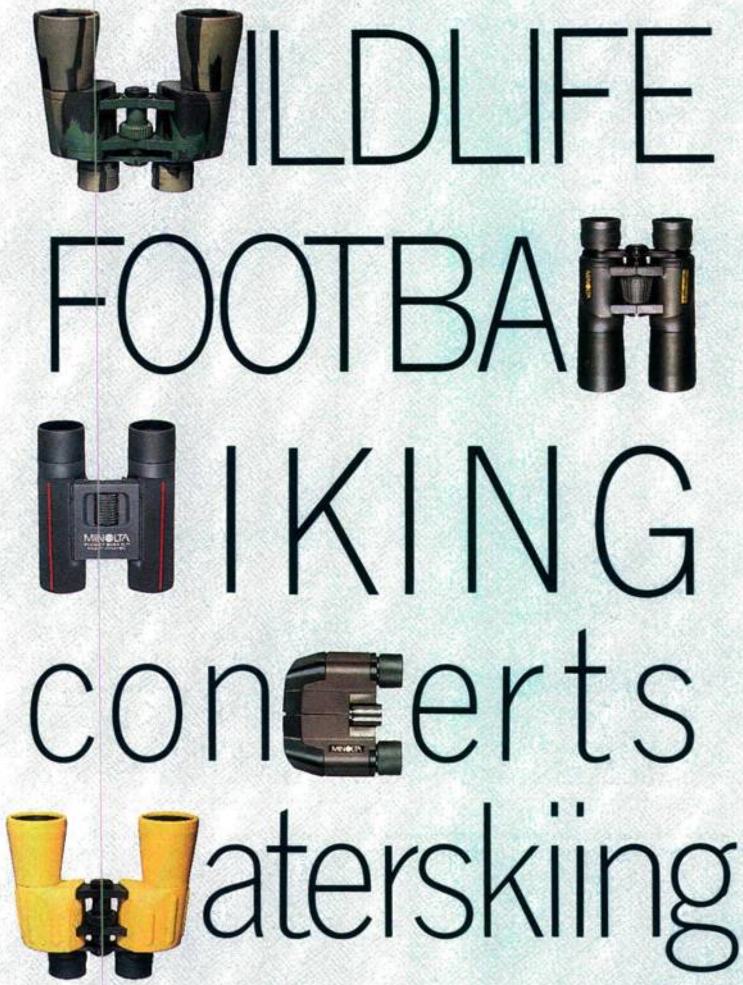
BRIGHT STARS, BIG MONEY

Harlan Smith talks to
ASTRONOMY's Robert Reeves

On August 31, 1989, Harlan Smith retired as director of McDonald Observatory, a position he held for the past twenty-six years. In that time Smith participated in and helped guide the explosive growth of astronomy as the science entered the Space Age. ASTRONOMY talked with Smith in Austin, Texas.

I became an astronomer almost by accident. Being sent to Harvard by the Army Air Corps for a brief special electronics training course during the Second World War, I returned there after the war with physics as my major. Harvard was one of only about four places in the country during the 1940s that had a really strong astronomy graduate program and a chance to work into it. That fact and an offer of an undergraduate job with Fred Whipple made me an astronomer instead of a physicist.

Back then the world of astronomy was really very leisurely paced. I



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A Small, Cozy World

In the 1940s astronomy was a cozy field. After Harvard I taught at Yale for ten years. During that time I agreed to be the acting secretary of the American Astronomical Society. There were only about 600 members and it was possible to know virtually every member of the society. It was really a very warm, friendly field to be in. Today there is still a lot of that friendliness, but as the field has exploded in the number of people, institutions, and specialties and in the competitiveness for funding, the graciousness isn't there like it was before.

On the other hand, the big characteristic of astronomy prior to 1960 was that almost nobody had any money. The exceptions were a few relatively wealthy institutions like Harvard, Chicago, and Caltech that did have some money and could support a handful of astronomers. The only other way you could hope to have a serious astronomy program was if a foundation like the Carnegie or the Rockefeller was willing to support an observatory. Or you had to go to private benefactors, as Harlow Shapley was successful in doing at Harvard. Basically, astronomy operated on a "gimme" basis.

Related to this was the fact that only a few Big Wheels had their expenses paid to go to national meetings. If you went to a meeting in the old days to give a paper, you paid your own way and you went because you thought you really had something to say.

A few of us students wanted to get to all the astronomical meetings in our half of the country. However, to have a car as a graduate student was beyond the reach of most people. But two of us did have Model A Fords. Mine cost $70 and I kept it in repair primarily with a pair of pliers and an adjustable wrench.

We would load four or five of us in each car and go to all the meetings that weren't hopelessly far away. Meals on the road were too expensive so we bought bread and peanut butter and ate that. Motels? They were two or three dollars a night! So we usually used sleeping bags. At three meetings I slept in a sleeping bag on the lawn of the observatory where the meeting was.

"Big Money" Arrives

Probably the biggest change has been the coming of "big money." This happened in the early 1960s with the advent of the space program. It became clear to a number of astronomers only gradually that space was where a lot of really important action would be.

One anecdote will reveal some attitudes of those days. While I was an instructor at Yale, NASA (then newly created) invited astronomers to help plan what space astronomy might be. I was asked by Professor Dirk Brouwer to represent Yale. I attended this planning meeting with about fifteen leading astronomers from all over the country. I was, of course, the pup of the litter.

I was stunned when a very distinguished astronomer got up and made an impassioned talk to the effect that astronomers should not buy into NASA on the grounds that its budget was outrageously large, and since it was primarily a manned program, NASA was simply trying to justify it by squeezing some science into it. There are probably some germs of truth in that, but nevertheless it seemed to me that the gains for astronomy by getting into space would be so overwhelming that we absolutely *had* to go along with NASA and help build the best space science program we could.

When nobody else spoke after that kickoff, I finally got up with a great deal of trepidation and made a few remarks on the positive side. When I sat down the man sitting next to me stuck his elbow in my ribs and whispered, "Gee, I'm glad you said that. If you didn't, I would have had to." I later found out that was Freeman Dyson, a great physicist from Princeton.

The point is, astronomers at that time were extremely wary of big money coming into the field, and they realized that a lot of it was not going to be spent directly or constructively for science.

Another big difference was the realization on the part of the U.S. government after the Second World War that science in a very literal sense had won the war and, by golly, now they were going to have to pay some attention to science.

The National Science Foundation got started in the mid-1950s and it was a relaxed and comfortable organization to work with. A letter, or almost even a phone call, pretty much sufficed for a proposal. Once, in fact, I was tele-

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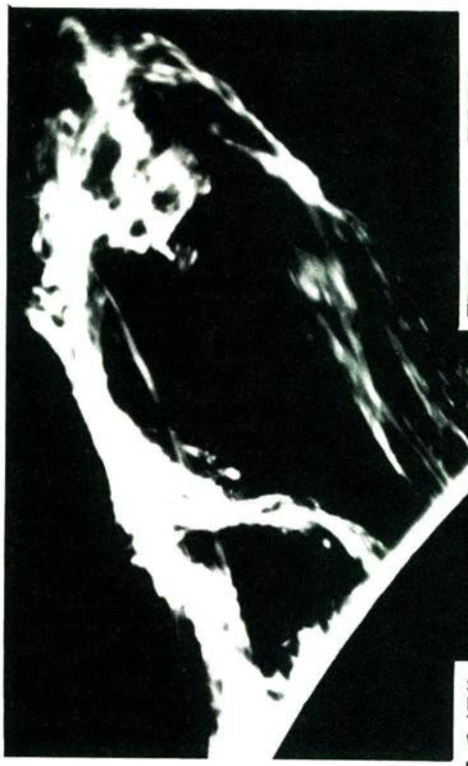

This remarkable photo is just one of many that the W. German Solar observer, Wolfgang Lille, has taken with the 7"f9 StarFire. Mr. Lille routinely captures subarcsecond detail on film, attesting to his skill as a solar photographer.

Solar Prominence Photo - 7"f9 StarFire Baader Planetarium Coronagraph TP2415 1/30 sec. @ f45 August 16, 1988 Wolfgang Lille, Hamburg, W. Germany

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phoned by an NSF representative who said, "Hey, we have some money left over. If you have any bright ideas on how to use it, send us a letter."

I remember that when I got my first substantial grant I had to buy a $5,000 fast recorder. It turned out to be exactly what we needed, but I felt guilty for days and weeks about spending $5,000 for a piece of scientific equipment. I had grown up in the period when to be given even $200 by the director to rebuild an instrument was manna from heaven. *That* was big money!

I think that feeling was not unique to me. I believe that with few exceptions, it took many astronomers a few years to adjust to the concept that what we were doing was not only important to ourselves but in some sense important enough to the country and the world that we didn't need to feel guilty about spending thousands, then hundreds of thousands, then millions, then hundreds of millions of dollars. I have done more than my share of this, having been one of seven astronomers on Lyman Spitzer's committee beginning in 1962 to promote what became the *Hubble Space Telescope*. In 1978-79 I also chaired the Space Science Board Committee in Space Astronomy and Astrophysics when we proposed the series of Great Orbiting Observatories.

Still, speaking for myself, the whole process of organized science has ground its gears with every order of magnitude change. It's been hard to adjust. I am still not comfortable serving on committees, even chairing committees, that ask for things that in the end cost several billion dollars. The principal rationalization that makes me feel less uncomfortable about it is knowing that vastly greater amounts are thrown away on things of absolutely no redeeming value whatever.

We had a surge for about ten years following Sputnik in which science support was very, very good in this country. We are still coasting on that. People were trained and facilities built. Unfortunately, politicians today are less aware than they should be about how important that initial support was in building the strength this country had back then. I see that sense of purpose rapidly eroding now.

The big money influx produced a great explosion in the power of our instruments over the past two decades. Not so much in bigger telescopes, although there is now a surge in them, but in the electronic detectors and analytical instruments. There have been great improvements in spectrographs and photometers. In particular the computer revolution has made it possible to use all these things far more efficiently and to analyze the prodigiously greater amounts of data that are produced now. This revolution is still very much in progress.

As a result of big money coming into astronomy, the role of an observatory director has changed. There was a time when the director of an observatory ran the organization and doled out the money. However, the advent of the research grant system in the early 1960s created a different sociology. Virtually all the scientists in a group like ours at McDonald are independent scientists who run their own fiefdoms. I mean that in a positive sense. They vigorously apply for grants and build their own sub-unit within the organization with independent funding that the director does not control. On the whole I think that's a healthy development. I think you could characterize the difference as one where the old-fashioned director told people what to do, while the modern director helps people do what they want to do.

A Lunar Future for Astronomy

The principal new area that I would like to become more active in is lunar-based astronomy. Suddenly, with the President's space address of July 1989, it has become clear that instead of being off in some nebulous future, the chances are good that NASA will get money — either unilaterally or, as I personally believe, in collaboration with Europe, Japan, and the Soviet Union — to return to the Moon, this time to occupy it permanently. The moment that happens, the Moon becomes an incredibly attractive place for astronomy.

The Moon of course has grand two-week-long dark nights for ultra-deep studies and for long continuous observations of variable stars. Yet its rotation allows you to see the whole sky visible from your latitude. If you have to follow a nova or supernova almost continuously, then of course you ultimately will need more than one observatory on the Moon. That too will come in time.

Some of us believe we should move onto the Moon as soon as we can, starting small but with magnificent goals so that eventually astronomical systems will be built on the Moon that may ultimately cost $100 billion. The whole world could contribute to the project over one or two generations and build grand instruments to really probe the universe for the human race. ☐

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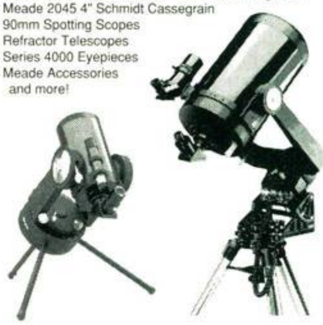

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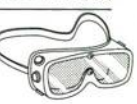

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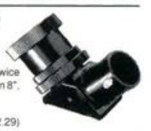

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Hughes' Currie with model of Hubble Space Telescope.

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OUR GALAXY IN THE NEAR INFRARED

If you thought the galaxy in the photo at right was a prominent edge-on spiral, you're correct. It's our galaxy, the Milky Way, seen at near-infrared wavelengths. The image was taken by the Diffuse Infrared Background Experiment on NASA's *Cosmic Background Explorer* satellite (*COBE*). The image was released in April at the annual meeting of the American Physical Society in Washington, D.C.

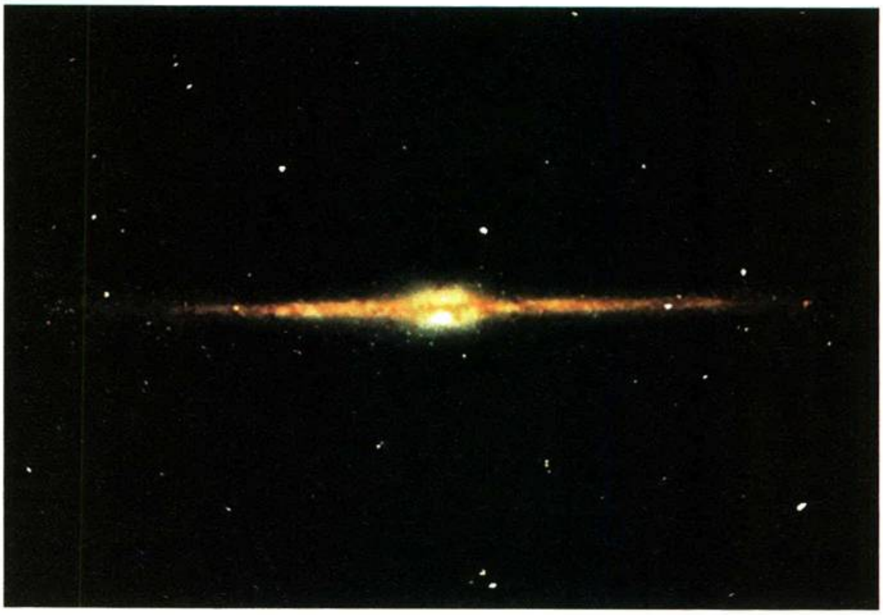
The image is actually a composite of images taken at 1.2, 2.2, and 3.4 microns, which are represented respectively as blue, green, and red. The plane of the Milky Way extends across the center of the photo and covers the region from the constellation Cygnus on the left (galactic longitude 96°) to Vela on the right (galactic longitude 264°). The North Galactic Pole is at the top.

The image shows the Galaxy's thin disk and the central bulge of the galactic center. Reddish clouds of absorbing interstellar dust bisect the disk. At the center of the Galaxy this absorption is so strong that the central part of the Milky Way is blocked at these wavelengths. The bright points of light scattered about the disk are individual stars near the Sun.

COBE's mission is to measure the cosmic background radiation — thought to be the remnant glow of the Big Bang — and search for any variations in its brightness. Such variations would represent the energy "imprints" of the first structures to form in the universe, the seeds of the galaxies.

Preliminary results released at the beginning of the year were in accord with the predictions of a smooth, uniform Big Bang; no deviations in the background were found by any of *COBE's* three instruments. Additional measurements made by *COBE* announced at the American Physical Society meeting continue to show a smooth, unperturbed background. Thus, until more sensitive maps are made by *COBE* later this year, the question of how galaxies formed in the early universe will remain unanswered. (See "Too Smooth: *COBE's* Perfect Universe," June 1990.)

The maps made late last year by *COBE's* Diffuse Infrared Background Experiment showed the bright infrared radiation from foreground sources — dust in our solar system as well as stars and interstellar dust in the Milky Way. Such foreground infrared radiation must be accounted for in order to find variations in the infrared background glow, the tell-tale evidence of the first stars and galaxies in the universe. The DIRBE has mapped the entire sky and will continue to map for another eighteen months or so when the mission is expected to conclude.



WHAT GALAXY IS THIS? The center of the Milky Way in the near-infrared displays a classic edge-on profile, complete with dust-obscured disk and prominent central bulge. This image was made by the Diffuse Infrared Background Experiment on the *Cosmic Background Explorer*. NASA/Goddard Space Flight Center photo.

CONSTRUCTION HALTED ON MOUNT GRAHAM OBSERVATORY

Construction of the Mount Graham International Observatory was halted on March 28 for 120 days by order of a U.S. District Judge so that a new environmental impact study can be conducted to address the observatory's effect on the Mount Graham Red Squirrel.

The injunction, ordered by U.S. District Judge Alfredo C. Marquez, directly affects the construction of roads and supporting structures for a submillimeter telescope and the Vatican Observatory's 1.8-meter Lennon telescope. Indirectly affected is the Columbus Project, an 8-meter binocular telescope being built by the University of Arizona, Ohio State University, and the Italian National Observatory.

Marquez, who had initially turned down a request to hear the case, ordered the injunction after two biologists who took part in early impact studies conducted by the U.S. Forest Service, the mountain's landlord, alleged that they had been told by their superior to argue in favor of construction.

Environmental groups, including the Sierra Club and Earth First!, say construction of the observatory could lead to the extinction of the squirrel, which is a subspecies of the Pine or Red Squirrel that inhabits all of Canada and most of the Rocky Mountain region. The Mount Graham Red Squirrel was isolated on the southern Arizona mountain top thousands of years ago when the climate changed at the end of the last ice age.

University of Arizona officials say years of hunting and recent poor crops of pine cones, the major source of food for the squirrels, have reduced the number of squirrels from 250 in 1987 to the current level of 180.

Opposition to the observatory has been steadily building since 1982 when the proposal was first announced. Complaints about the impact of a proposed two-lane, paved access road to the top of the mountain were first raised by hunters who were afraid the mountain top would be overrun by weekend sightseers.

About the same time the plight of the Mount Graham Red Squirrel was raised by environmental groups. After initial opposition from the University of Arizona, the squirrel was placed on the endangered species list. Later, however, the university pledged millions of dollars for programs to monitor and help the squirrel. But the university also managed to have the Arizona congressional delegation sponsor an act of Congress that forced the Forest Service to issue a permit allowing construction after a compromise on the size of the facility was reached. University officials based their course of action on the Forest Service study, which showed that the construction would have little or no impact on the squirrel.

The result was that more environmental groups entered the fray because they feared the event could spark a precedent that would give Congress more direct control over the environment. Environmentalists feared this would reduce the power of current environmental procedures and laws, which are administered through government agencies such as the Forest Service and the Environmental Protection Agency.

With stronger backing and more funding, the newly formed Mount Graham Coalition filed suit in court to test Congress' ordering of the construction permit. Michael D'Amico of Earth First! said the coalition is committed to underwriting the tremendous court costs in order to overturn a bad precedent of how Congress can negate the nation's environmental laws. — *Robert Bunge*

NEW COMPANION GALAXY FOUND

Quick, how many satellite galaxies does the Milky Way have? Just two? Although the Large and Small Magellanic Clouds are the best known of the Milky Way's small companion galaxies, a new discovery brings the total count to ten.

The latest MIlky Way companion was discovered in February by Mike Irwin, Richard McMahon, Pete Bunclark, and Mike Bridgeland of the Institute of Astronomy at the University of Cambridge, England. The galaxy is located in the constellation Sextans and is only 275,000 light-years away, barely three times the diameter of the Milky Way. Because of its proximity this galaxy appears large, about 1.5° across. The reason this neighbor went undetected for so long is that it is exceedingly faint. In fact the new companion galaxy has the lowest luminosity of any known galaxy and contains stars no brighter than 20th magnitude.

The Sextans object is an example of a dwarf galaxy, a class of small, low-mass galaxies only a few thousand light-years in diameter. Harlow Shapley discovered the first examples of dwarf satellite galaxies in 1938, one in the constellation Sculptor and one in Fornax. Four more were found in the 1950s. Two are in Leo, one in Draco, and one in Ursa

Amateur News

ASTRONOMERS UNITE AGAINST LIGHT

The International Dark-Sky Association, Inc., the nation's leading organization combating light pollution, held its second annual meeting in Tucson, Arizona, on April 7-8. Forty astronomers, civil engineers, educators, and citizens attended the meeting, which included paper sessions, a banquet, and a business meeting.

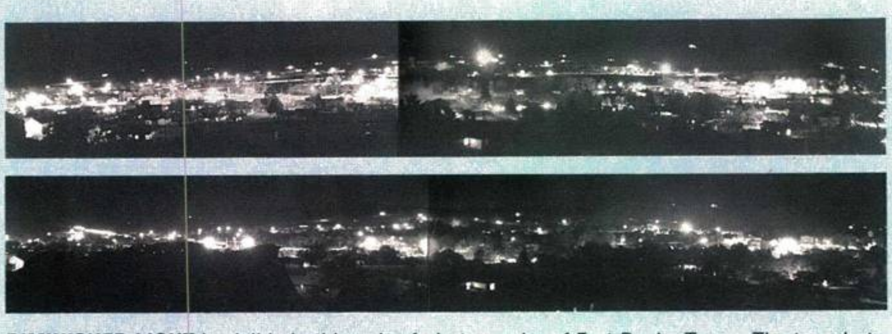
"The papers formed the core of the meeting and showed an increasing dedication to preserving a usable night sky," said Tim Hunter, IDA president. Dick Guthrie, city electrical engineer for Tucson, outlined design plans for proper street lighting and goals for the next decade in the Tucson area. Burt Nelson reported on light pollution in the San Diego area, where the city council voted seven to two to preserve lighting conditions favorable to astronomy. Wes Lockwood of Lowell Observatory and Chris Luginbuhl of the U.S. Naval Observatory discussed the lighting code for Flagstaff, Arizona, the strictest in the United States.

All of the news wasn't so good, however. John Leech of Orlando, Florida, displayed sets of photos that showed the seriousness of the growing light pollution problem around Orlando. Ruth Lewis from Calgary, Alberta, reported that the situation in parts of Canada is just as bad.

Long-term plans include improving many targeted areas where light pollution victories are possible. Ed Barker of McDonald Observatory explained how funds raised at the Texas Star Party have been used in Fort Davis, Texas, in an ongoing program to retrofit 400-watt mercury vapor fixtures to fully shielded 90-watt low-pressure sodium fixtures.

IDA board member and attorney Dan Knauss discussed how light pollution can be stopped on legal grounds as light trespass. Tucson amateur David Levy suggested that astronomers would be well advised to start fighting the next generation of light pollution by getting today's kids interested in astronomy and backyard observing.

For more information on the organization, write to the International Darksky Association, 3545 North Stewart, Tucson, AZ 85716.



DIMINISHED LIGHT is visible in this pair of photographs of Fort Davis, Texas. The top photo shows the community before light pollution ordinances were passed; the bottom photo shows diminished skyglow afterward. Photos by Ed Barker.

Minor. The last dwarf galaxy was found in 1977 in the southern constellation Carina.

Although sharp-eyed amateur astronomers have claimed to have seen some of these objects, the dwarfs were all discovered photographically. The Carina and the new Sextans dwarfs were both found with automatic plate-scanning machines that were able to detect subtle variations in brightness across a region of a photograph.

"The discovery of the Sextans dwarf was a by-product of our search for distant quasars," said codiscoverer Richard McMahon. "So far we have surveyed about one-quarter of the sky available to us and we've come across one new dwarf galaxy. If we are lucky, we may find three more. Or we could find none."

THE BRIGHTEST GAMMA RAY STAR CONFIRMED

If your eyes could see gamma rays, the brightest "star" in the sky would be in the horns of Taurus, just north of Zeta Tauri. To our normal "white light" eyes there is only a faint patch of light marking the spot. This innocuous looking object is the Crab Nebula, the remains of a star that exploded over 900 years ago. It contains a pulsar that is a source of radio waves and X rays.

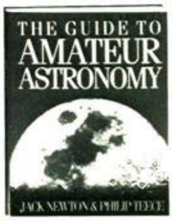
Now a team of astronomers working at the Smithsonian Institution's Whipple Observatory in Arizona have conclusively established the Crab Nebula as the strongest source of gamma rays in the sky. The actual source of the gamma radiation is likely the Crab's pulsar, a rapidly spinning neutron star at the heart of the nebula. The pulsar's rotating magnetic field accelerates electrons to near the speed of light. The energetic electrons interact with low-energy photons to produce high-energy gamma rays.

These gamma rays were detected with a remarkable instrument, a collection of hexagonal mirrors in an array 10 meters across located on Mount Hopkins, south of Tucson. Such a light bucket can't detect gamma rays directly; instead the 10-meter array looks for faint emissions of blue light that last only 10 billionths of a second. These emissions, called Cerenkov radiation, are emitted in Earth's upper atmosphere by the passage of sub-atomic particles created by the incoming gamma rays.

The Whipple Observatory's Cerenkov detector has been in operation since 1969, but in 1988 a new high-resolution camera was installed at its focus. "With this camera," explained Richard Lamb of Iowa State University, "we can fix the position of a source in one dimension to an accuracy of 0.1°." While it has long been suspected that the Crab was a gamma-ray source, the recent observations are the first conclusive evidence. Says Lamb: "Compared to other gamma-ray sources that last only minutes or hours, the Crab is steady and indisputable. It is rock solid month after month."

HOW BLOW THE WINDS OF TRITON?

The nitrogen atmosphere of Neptune's large moon Triton behaves much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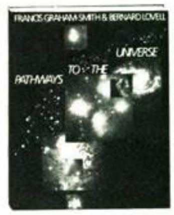
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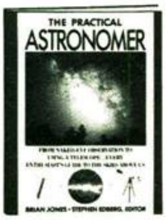
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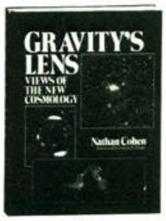
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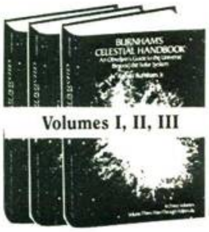
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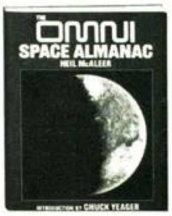
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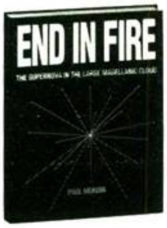

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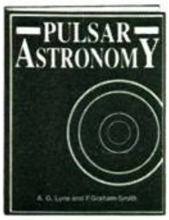
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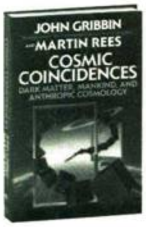
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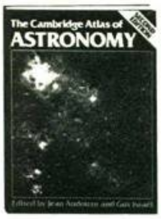
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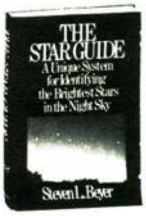
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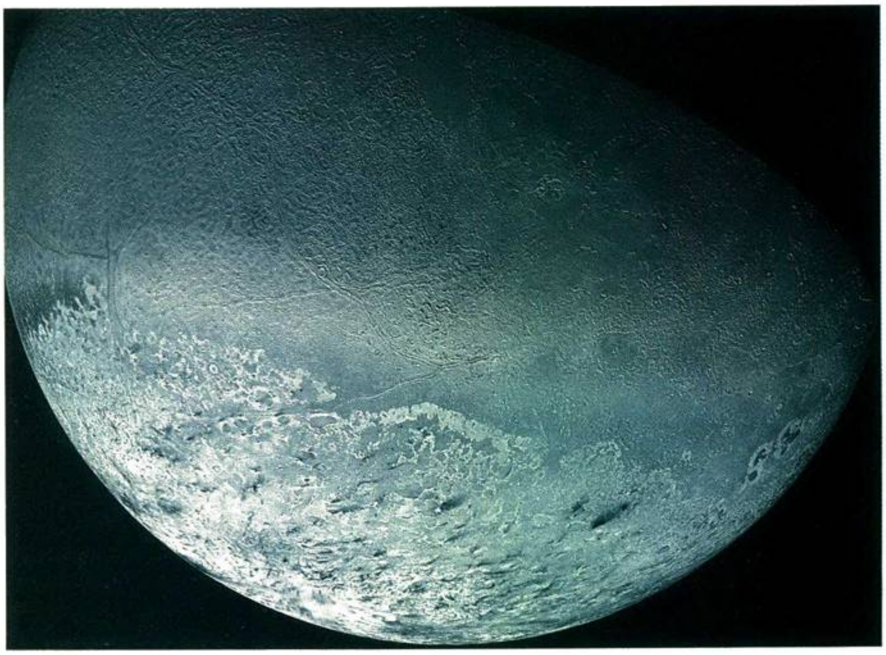
like a deep-frozen Mars, says Andrew Ingersoll, a planetary scientist at the California Institute of Technology. He has proposed (*Nature*, March 22, 1990) an explanation for Triton's atmospheric motions that takes into account *Voyager* data and theoretical modeling. The new theory also explains the unusual structure of the geyser plume (AstroNews, January 1990) that jets straight up about 5 miles before sharply bending horizontal and streaming westward a distance of 60 miles. Another *Voyager* observation accounted for is why the many dark windstreaks on the surface run northeastward but the plume is streaming westward.

According to Ingersoll the atmospheres of both Mars and Triton are in equilibrium with their polar caps, which means that part of the atmosphere alternately freezes out as frost or sublimates back into a gas, depending on the local seasonal energy input. And yet, Ingersoll points out, "the analogy isn't perfect." At any point in the Martian year Mars' carbon dioxide atmosphere has about three to five times



BLACK STREAKS RUN northeastward from many craters in Triton's southern hemisphere, a feature explained by a new theory of Triton's winds.

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more mass than the frosts that seasonally condense. With Triton, however, the seasonal frost deposits in each of the polar caps have about ninety times the mass of what is in the atmosphere at any one time. Thus on Triton there is a much larger seasonal transfer between the surface and the atmosphere.

What this means for the motions of winds on Triton is that frost sublimates and adds to the atmosphere over the sunlit polar cap, which is currently the southern one. This creates a wind flowing out from the pole in all longitudes, but because Triton is rotating (counterclockwise when you view the south pole straight on), Coriolis force bends the polar wind toward the right and turns what would be a north-flowing wind into one moving northeastward. At ground level, where the winds blow with speeds of 10 to 30 miles per hour, this produces the northeast trending streaks.

But what about the westward streaming plume? The wind pushing on the plume comes from a poleward flow at higher altitudes that is driven by the temperature contrast between the cold pole and the relatively warm equator. Coriolis force also affects this flow, once again bending it toward the right relative to the surface. But because this high-altitude wind is moving south, the right-hand deflection turns it westward. Thus, says Ingersoll, the upper part of the geyser plume is blown in the opposite direction from the surface streaks.

PBS SERIES FOCUSES ON ASTRONOMY

This autumn the Public Broadcasting System will air a six-part series on current activities in modern astronomy. A production of Los Angeles public television station KCET-TV, "The Astronomers" was made possible by a $5.3 million grant from the W. M. Keck Foundation, the same organization that funded the 10-meter Keck Telescope on Mauna Kea, Hawaii. The series will be broadcast in six one-hour episodes. Viewers should check local program listings for broadcast times.

Cameras taping for the series have already visited the Soviet Union, Chile, Japan, England, Italy, and France, as well as the United States, the producers reported. The series will examine how astronomy works, what is happening on the cutting edge of astronomical research, and who is doing it. The advisory board includes David DeVorkin of the National Air and Space Museum, Mark Morris of UCLA, Frank Shu and Joseph Silk of the University of California at Berkeley, and Virginia Trimble of the University of California at Irvine.

GIOTTO *REACTIVATED FOR NEW MISSION*

When we last left the European Space Agency's *Giotto* spacecraft, it was being put into "hibernation mode" following its spectacular 1986 flyby of Comet Halley. Now, after nearly four years in hibernation, the probe has been reawakened for a new mission: a close flyby of Comet Grigg-Skjellerup in 1992.

When *Giotto* flew within 375 miles of Halley on March 13, 1986, it was damaged by an intense bombardment of dust particles jetting from the comet's nucleus. Four of the nine scientific experiments on board the craft were knocked either partially or totally out of order by high-speed dust impacts. Fortunately the spacecraft used only about 10 percent of its hydrazine fuel supply to reach Halley. With enough functioning instruments to make another flyby worthwhile and enough fuel to redirect the craft, ESA planners decided to reactivate *Giotto* for a second mission.

On February 19 of this year ESA's European Space Operations Center transmitted a "wake-up call" to *Giotto* via NASA's Deep Space Network antenna near Madrid, Spain. The spacecraft responded by orienting its high-gain antenna toward Earth and sending back telemetry data. *Giotto* appears to be in good shape even though it is a bit warmer than expected, most likely as a result of damage to the thermal insulation during the Halley encounter. That shouldn't pose much of a problem, however, because the probe is now heading away from the Sun.

In mid-March the *Giotto* mission control team fired the spacecraft's thrusters to redirect it toward Earth. On July 2 the spacecraft will pass just 14,300 miles from Earth, receiving a gravity assist to head it toward Comet Grigg-Skjellerup. A month later *Giotto* will go into hibernation once more, to be reactivated a few months before the July 10, 1992, flyby.

HIPPARCOS *SURVIVES LONG ECLIPSES*

The European Space Agency's *Hipparcos* satellite survived a potentially damaging series of eclipses in March and now appears ready to achieve a significant portion of its scientific mission. Astronomers hope that the satellite, which failed to reach the proper orbit after its launch in August 1989, can still determine accurate positions and motions for over 100,000 stars during the next two and a half years.

The long eclipses were a direct result of the highly elliptical orbit *Hipparcos* was stuck in when its boost motor failed. Although the spacecraft would have been eclipsed in the circular orbit originally envisioned, the duration of the eclipses would have been relatively short. Astronomers weren't sure that the solar arrays could generate enough electricity to keep the spacecraft's batteries charged during the longer eclipses encountered in the actual elliptical orbit.

The worst eclipse occurred on March 16 when *Hipparcos* remained in Earth's shadow for 105 consecutive minutes. The satellite came out of the eclipse series with barely five minutes of battery power left.

Now that *Hipparcos* has survived this critical test, astronomers are cautiously optimistic that the mission will be a success. Michael Perryman, European Space Agency project scientist, said: "We have known since November that the technology and system concept underlying the *Hipparcos* mission have been fully demonstrated. With the successful emergence from the long eclipse season and good prospects that the satellite can survive for another two and a half years, the original scientific goals of the mission may still be within our grasp." □

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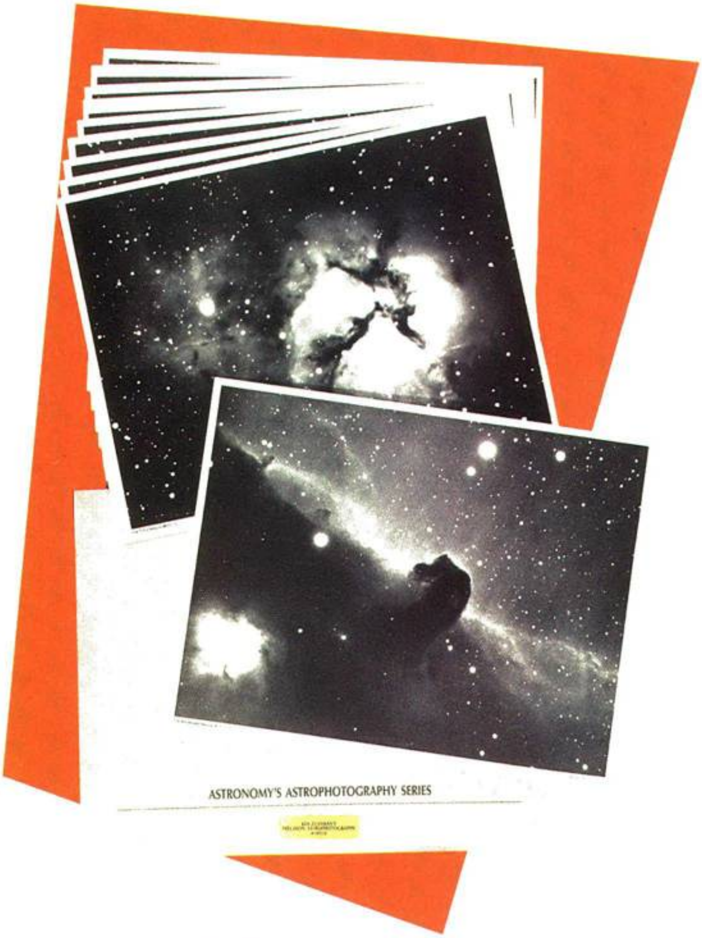

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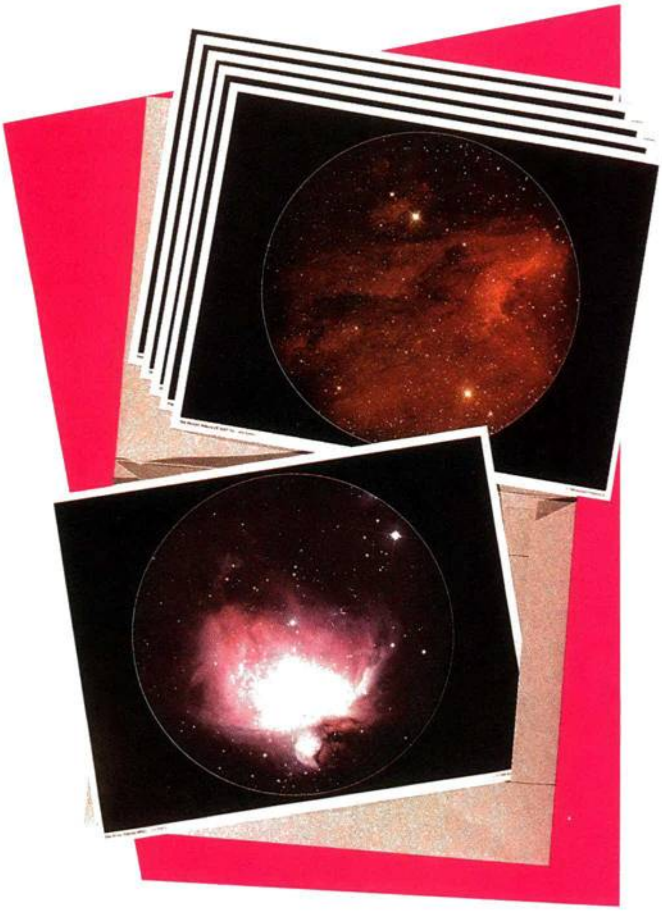

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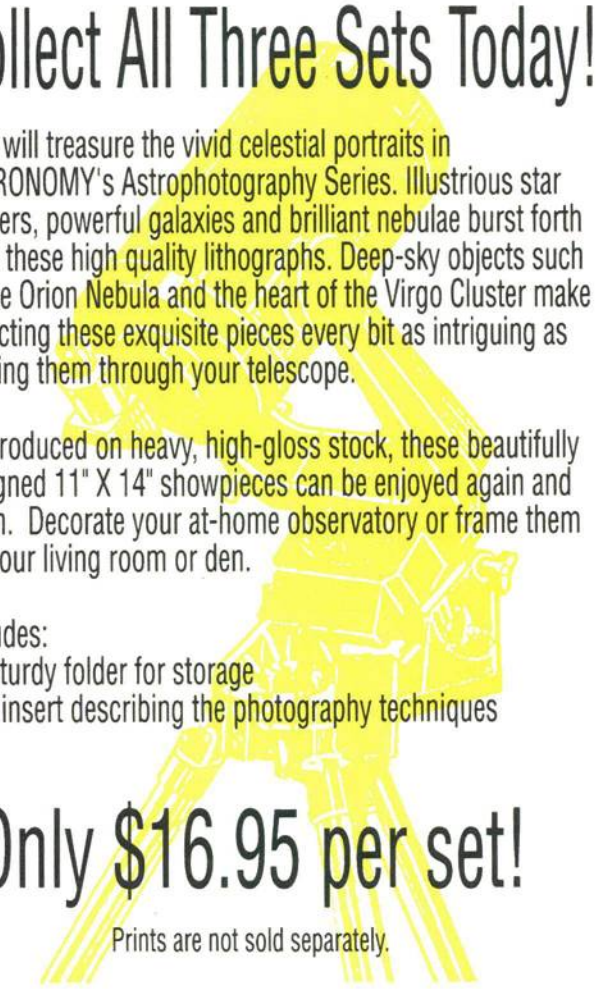

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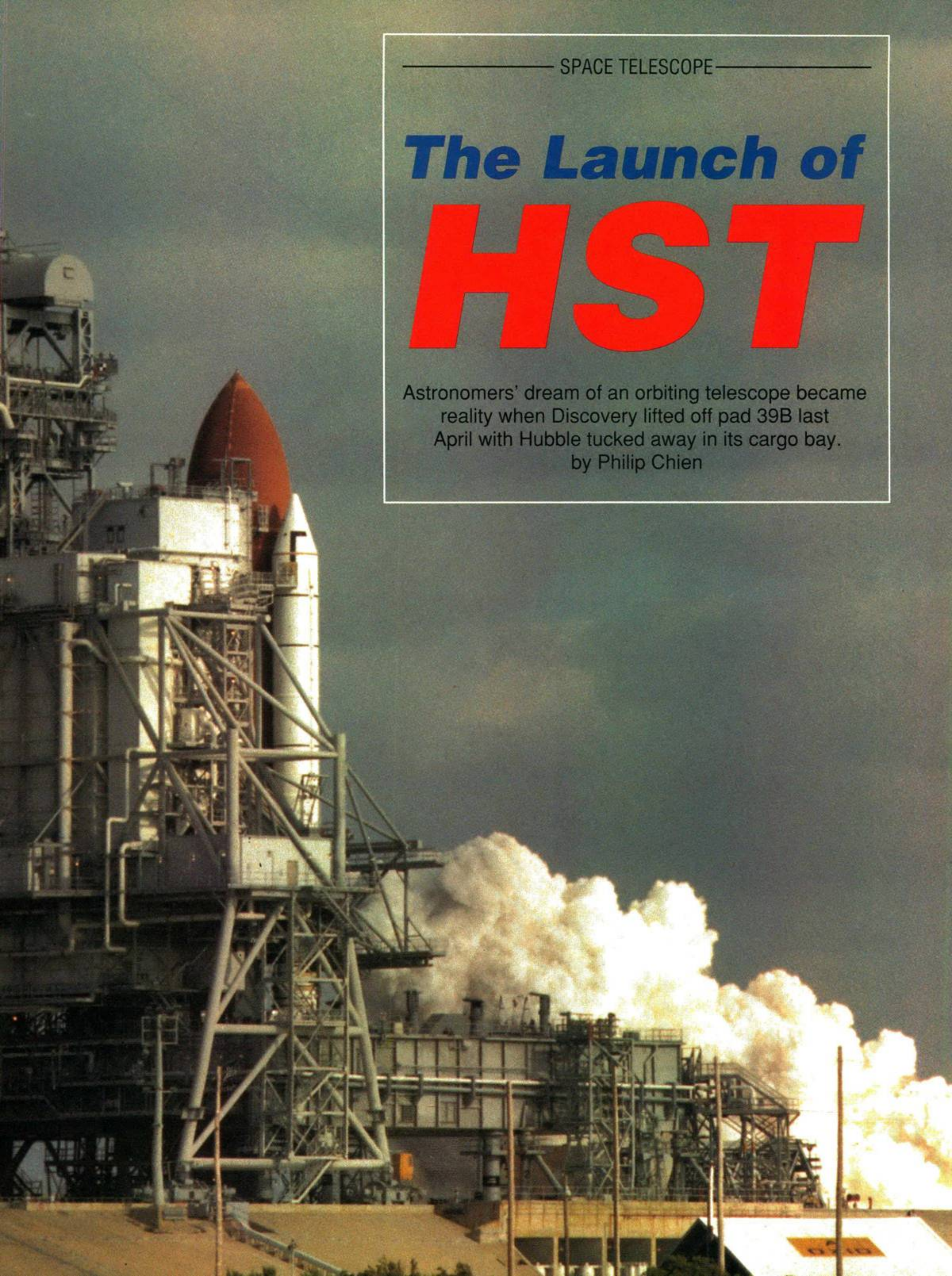
The Launch of HST

Astronomers' dream of an orbiting telescope became reality when Discovery lifted off pad 39B last April with Hubble tucked away in its cargo bay.

by Philip Chien



DISCOVERY CLIMBS SKYWARD. In the foreground, *Columbia* is being readied for the launch of *Astro 1*. NASA photo.

NASA's STS-31 space shuttle flight on April 24 was very similar to other shuttle flights, but the "package" that lay in *Discovery's* cargo bay was far from commonplace. Thirty-one hours after launch the astronauts carefully released the most anxiously awaited payload since the shuttle program was conceived: the *Hubble Space Telescope*.

Launch day dawned bright and clear. All systems were operating perfectly on both the shuttle and *Hubble*. In attendance at the Kennedy Space Center were many *Hubble* scientists and their families, hoping to witness the culmination of two decades' worth of work. Project scientist Albert Boggess and his wife, Nancy, deputy project scientist for the *Cosmic Background Explorer* satellite, were visibly excited as the clock counted towards zero. This was their second trip to the Cape. The first launch attempt on April 10 was scrubbed when a power unit aboard *Discovery* malfunctioned, requiring a two-week delay.

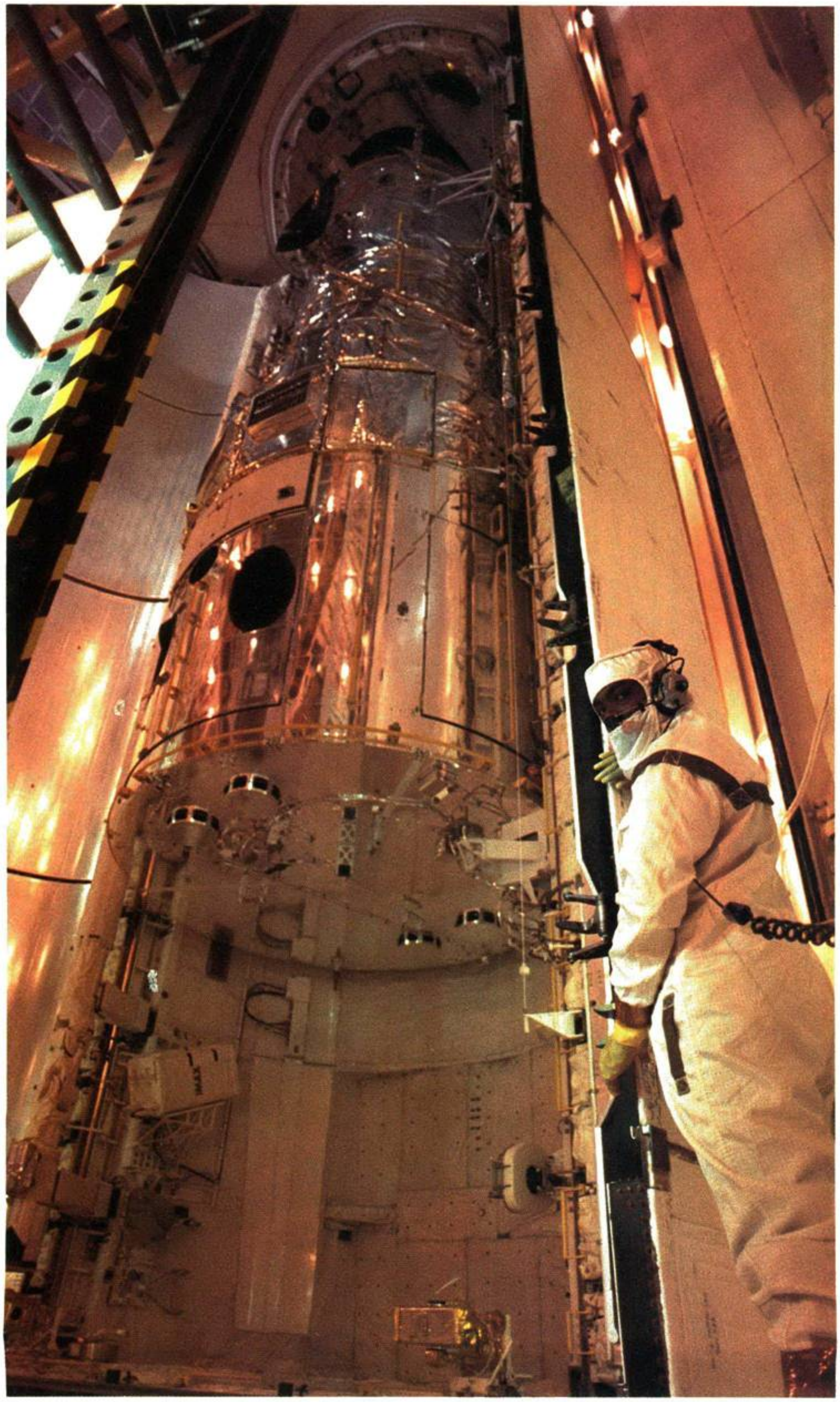
But now that problem was fixed, the clock was ticking, and it seemed the world was ready for *Hubble* to get on with its fifteen-year mission to study the universe. At 8:22 a.m. EDT, the countdown clock came out of its last planned hold at T-minus nine minutes. Tension charged the air.

Then at T-minus 31 seconds the countdown went into an automatic hold. The sensor for the liquid oxygen fill and drain valve, which is used to load the shuttle's external tank, indicated that the valve was in the wrong position. For a few anxious moments it looked like another scrub was in the offing. But a quick check showed that the valve was okay. Disappointment abruptly turned to anticipation again as the countdown resumed and the clock ticked down the final seconds.

At 8:33:51 a.m. the deafening roar of the solid rocket boosters filled the air and the shuttle leapt from the pad into an almost straight-up ascent. An unusually vertical flight path was required because *Discovery* was aiming towards a 380-mile high orbit, the record height for a space shuttle and an altitude last achieved by *Apollo 17* eighteen years before.

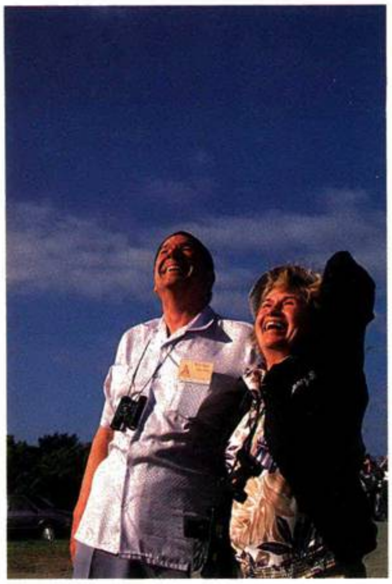
Al Boggess stood speechless as he watched the shuttle climb into the sky on a cone of fire and smoke. Nancy was more animated and shouted "*Hubble* go!" A minute later, the shuttle was moving at the speed of sound and still accelerating. In two minutes the shuttle was thirty miles downrange and the solid rocket boosters fell away. In less than five minutes the shuttle was out of sight. *Hubble* was on its way into science history.

Astronomers have dreamed of orbiting space telescopes since the end of World War Two, when sounding rockets first carried small telescopes into space for quick glimpses of the universe free of the blurring effects of Earth's atmosphere. *Hubble* is the



DISCOVERY'S PAYLOAD DOORS close around *Hubble* under the watchful eye of a technician. NASA photo.

EDWIN HUBBLE'S DESCENDANTS (in yellow caps) track the progress of *Discovery* as it carries aloft the telescope named in honor of their forebear. Photo by Allen Fredrickson.



AS DISCOVERY LIFTED OFF, NASA scientists Albert and Nancy Boggess were there to witness the beginning of a new era in astronomy. Photo by Michael Hahn.

fulfillment of that dream, though its launch, like other astronomy space missions, was a long time coming.

The preliminary 1980 shuttle manifest, produced a year before the first shuttle flight, listed *Hubble* as the twenty-fifth flight on December 15, 1983. But by August 1983, delays had pushed the launch back to August 1986.

And then the *Challenger* exploded in January 1986. Although most shuttle crews were assigned to other duties in the wake of the accident, the *Hubble* crew was unofficially told to continue their training. Within a year, however, John Young, the original commander of the *Hubble* mission, was named deputy director of flight operations at the Johnson Space Center in Houston. Replacing him as commander was Loren Shriver. The rest of the astronaut team — pilot Charlie Bolden and mission specialists Kathy Sullivan, Bruce McCandless II, and Steve Hawley — remained intact.

On September 30, 1989, *Hubble* was lowered from the vertical to horizontal position for the final time at Lockheed's Sunnyvale, California, clean room to prepare it for shipping to the Kennedy Space Center. At Kennedy, *Hubble* was prepared for flight in the Vertical Processing Facility, a clean room where large payloads are prepared for launch using a simulated shuttle cargo bay test stand.

Extraordinary precautions were taken to prevent any contamination of *Hubble's* sensitive instruments during its stay at Kennedy. *Hubble* was encapsulated in a special plastic wrap "cocoon," except when it was serviced. Visitors to the processing areas were instructed not to wear any perfume or makeup for fear the residue would corrode or contaminate the delicate parts of the telescope. In addition, burning leaves and garbage on the Kennedy grounds was put on hold several months before the launch to reduce particulate levels in the air.

For six months *Hubble* went through the final preflight diagnostics, installation, and testing of the science instruments and flight batteries, as well as communications checks. *Hubble* was then placed in the payload canister for transport to the launch pad payload changeout room for loading into the shuttle.

Hubble was rolled out to the launch pad on March 25, and was scheduled to be placed in the shuttle on the 27th. The installation was delayed, however, due to an infestation of midge flies, small mosquito-like bugs, on *Discovery's* cargo bay doors. Using vaporous insecticides to kill off the pests was out of the question; the threat of contamination was too great. So five special traps

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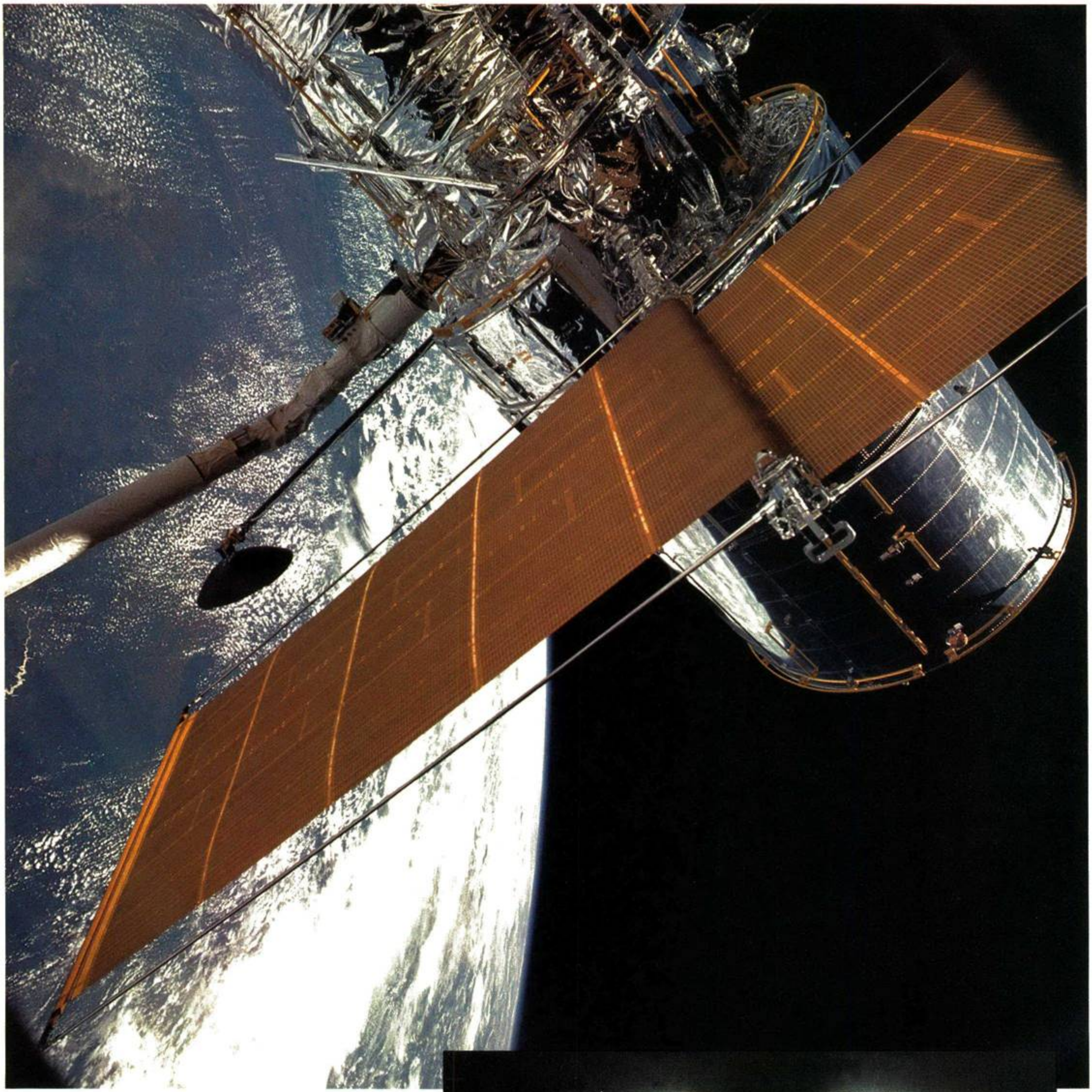
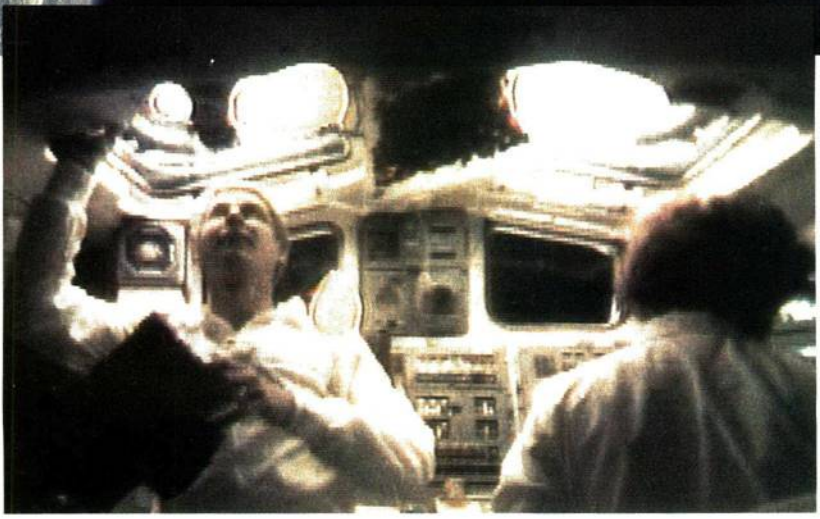
HUBBLE'S 15-YEAR MISSION began with a flawless launch from pad 39B. Photos by Allen Fredrickson.



THE REMOTE MANIPULATOR ARM positions *Hubble* for release following the deployment of the telescope's solar arrays. NASA photo.



SHUTTLE ASTRONAUTS Steve Hawley (left) and Kathy Sullivan prepare to deploy *Hubble* from the shuttle's aft flight deck. NASA Select Television photo.

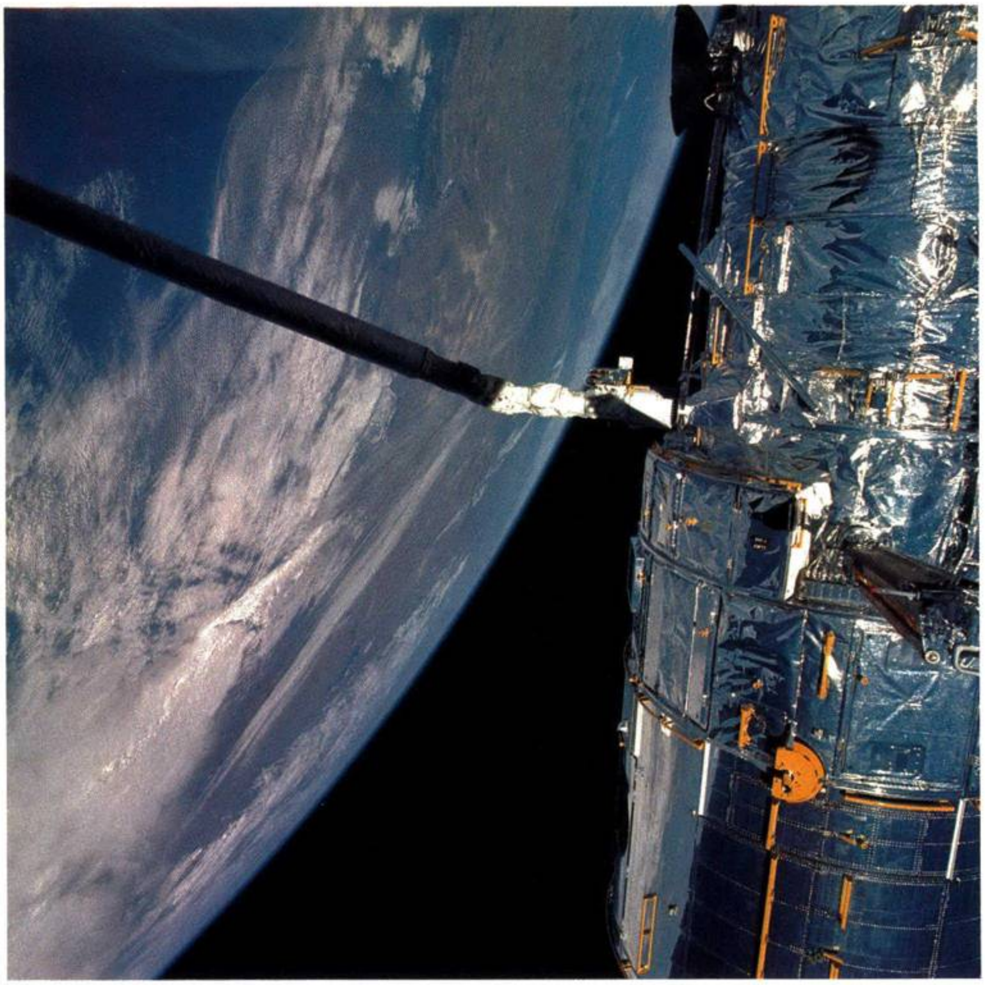
were set up and monitored by technicians every hour. The next day, with the midge count within tolerable limits, NASA officials gave a go-ahead to insert *Hubble* into the cargo bay.

If it wasn't midges it was hardware. A precautionary changeout of the right aft solid rocket booster segment set the launch date back to April 18. It turned out, however, that less time was needed than anticipated for the changeout and the launch was moved forward to April 10. But this attempt was scrubbed because one of the three auxiliary power units in the shuttle wasn't working properly. These units generate power for the orbiter's hydraulic system, which in turn gimbals the main engines during launch and operates the control surfaces — elevons and rudder — during landing. It would be two more weeks before a second and successful launch attempt was made. On April 24, *Hubble* finally made it into space.

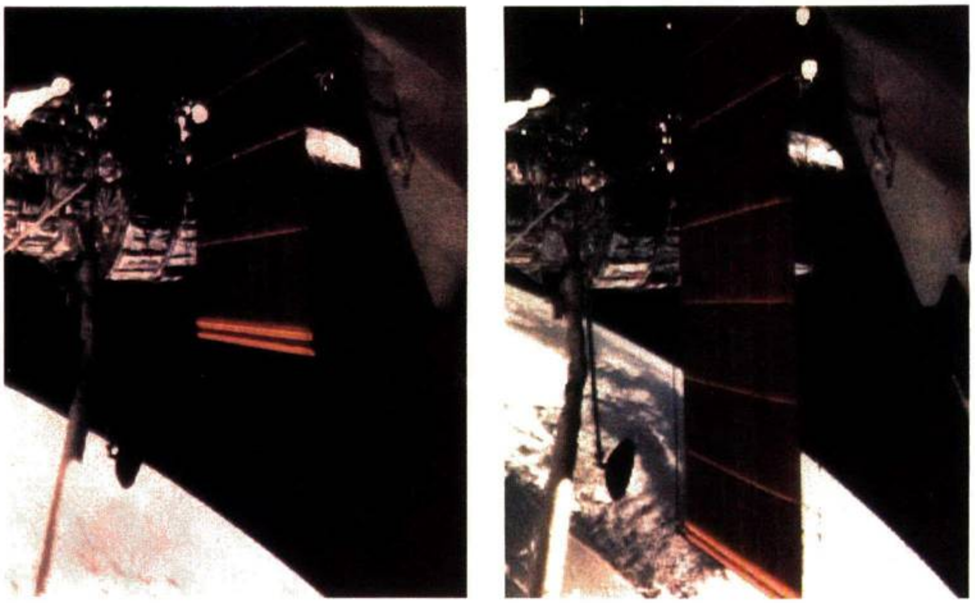
During launch *Discovery* provided power to *Hubble* by an umbilical power cord. Twenty-three hours into the flight the umbilical was detached and *Hubble* was switched to battery power. Without power from the shuttle, *Hubble* had only eight hours of onboard power, making deployment of the solar arrays critical to prevent the batteries from running down. Astronauts Kathy Sullivan and Bruce McCandless were prepared for an emergency spacewalk to unfurl the arrays manually if necessary, and went so far as donning their EVA undergarments.

An hour after umbilical release astronomer/astronaut Steve Hawley lifted *Hubble* with the remote manipulating system and rotated it to the deploy position. The deployment was slightly behind schedule but nobody was worried. Better to take it slow and easy than do anything wrong. After the solar array booms rose from their canisters, they were supposed to unfurl. The port array deployed normally but the starboard array stopped suddenly before completely unfurling. An indicator showed too much tension in the array and automatically stopped the deployment.

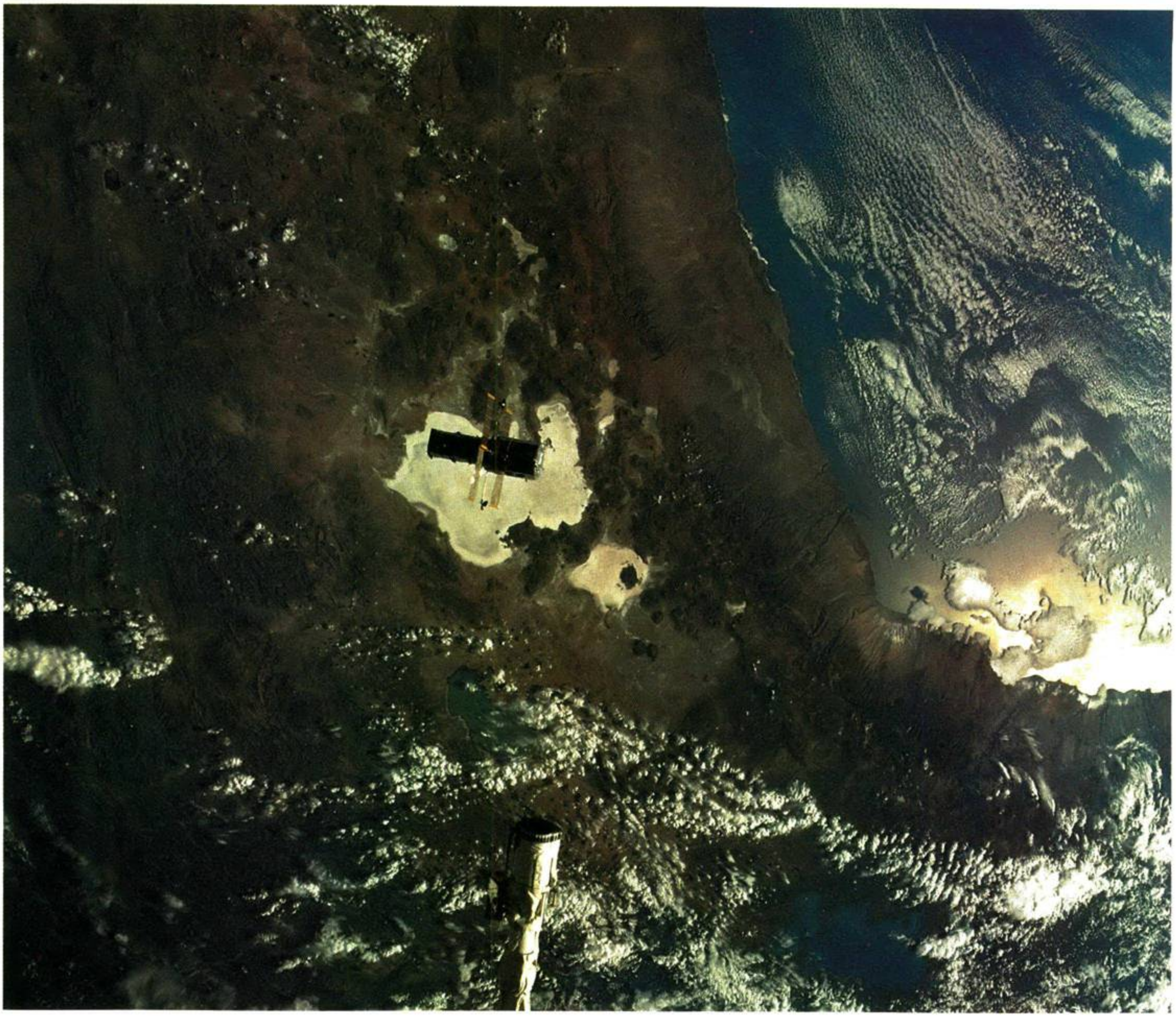
In the airlock, Sullivan and McCandless were suited up and had started depressurizing the airlock to prepare to go outside and manually open the array. While the orbital verification team at Goddard Space Flight Center in Maryland worked on the balky starboard array, the S-band antennas used to send commands to *Hubble* and relay data back to the



THE BUSINESS END of the telescope is seen in this photo taken as *Hubble* was lifted out of *Discovery*. Instruments, batteries, and computers are accessible via equipment bays (yellow handles). NASA photo.



HUBBLE's PORT SOLAR ARRAY begins to unfurl. The starboard array (out of the frame) proved difficult to open at first. In the photo at right the solar array is fully deployed. NASA Select Television photo.



FREE AT LAST, the *Hubble Space Telescope* drifts away from *Discovery* above Peru. Lake Titicaca is at upper right. The chalky feature (center) is Salar de Uyuni. NASA photo. Sean Sullivan of Palm Bay, Florida, photographed *Discovery* and *Hubble* (fainter streak) flying in tandem on the morning of April 26.

ground were opened, the aperture door latch was released, and other pre-deployment activities were completed. Fortunately, after three tries the tension-monitoring software was bypassed and the arrays slowly expanded to catch the sunlight.

Capcom Story Musgrave radioed up, "*Discovery*, go for *Hubble* release." Everything was finally ready.

At 2:39 p.m. on April 25 Steve Hawley pressed a trigger on his RMS control panel releasing *Hubble* from the shuttle's grip. After confirming everything was okay, Loren Shriver fired *Discovery's* thrusters to put some distance between the shuttle and *Hubble*. The Johnson Space Center public affairs officer then announced, "The first of NASA's great observatories is now on station at 330 nautical miles above the Earth." Shuttle pilot Charlie Bolden said tersely, "step one is complete."

Two days later, after some communication problems with the telescope, the aperture door was opened and another milestone was passed. Musgrave informed the crew: "*Discovery, Hubble* is open for business." Steve Hawley replied, "That's outstanding! Thank you Story." A moment later, Hawley asked, "I don't suppose they'd want to give me any time on it, would they?" "I'll give you all the time you'd like, Steve-O," Musgrave said. □

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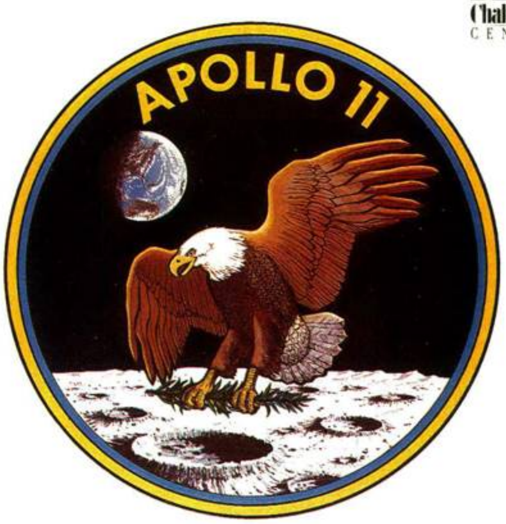

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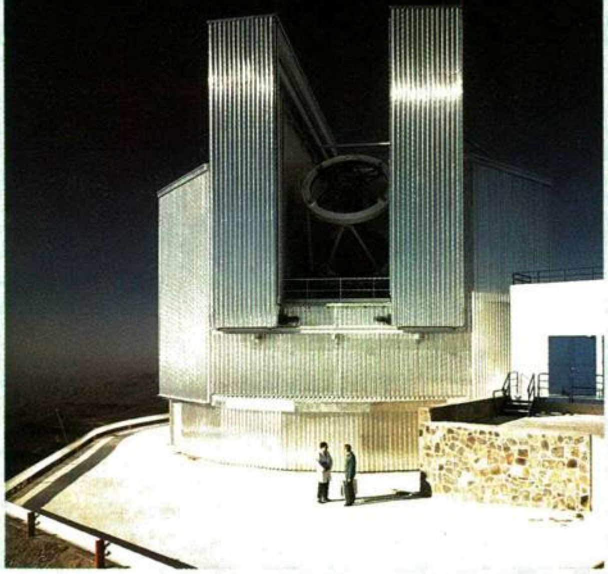

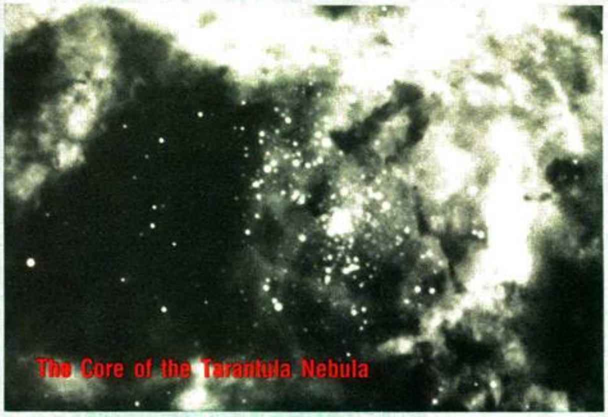

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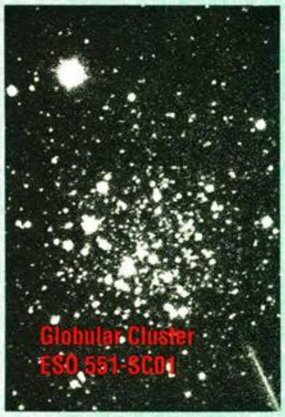

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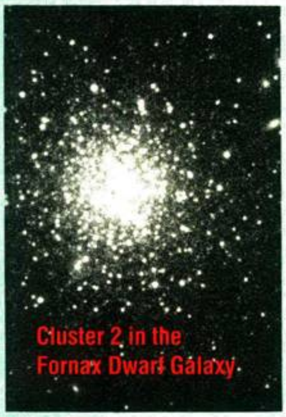

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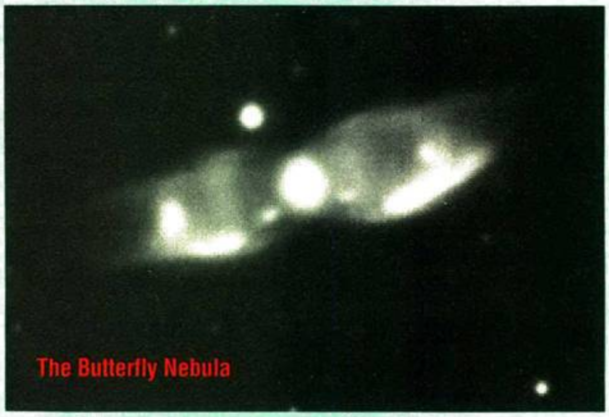
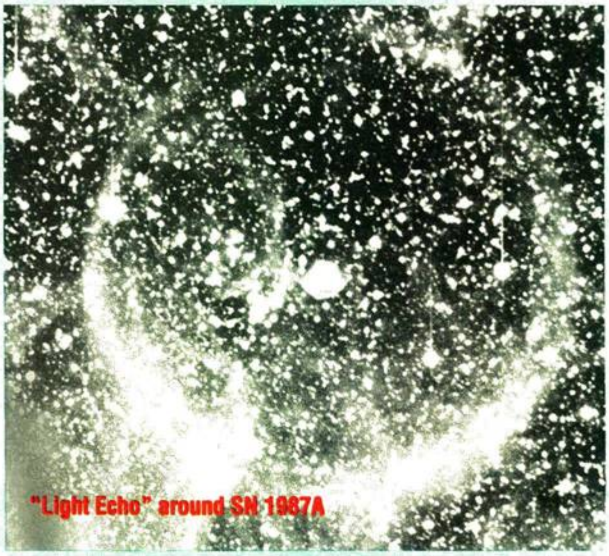


The Butterfly Nebula

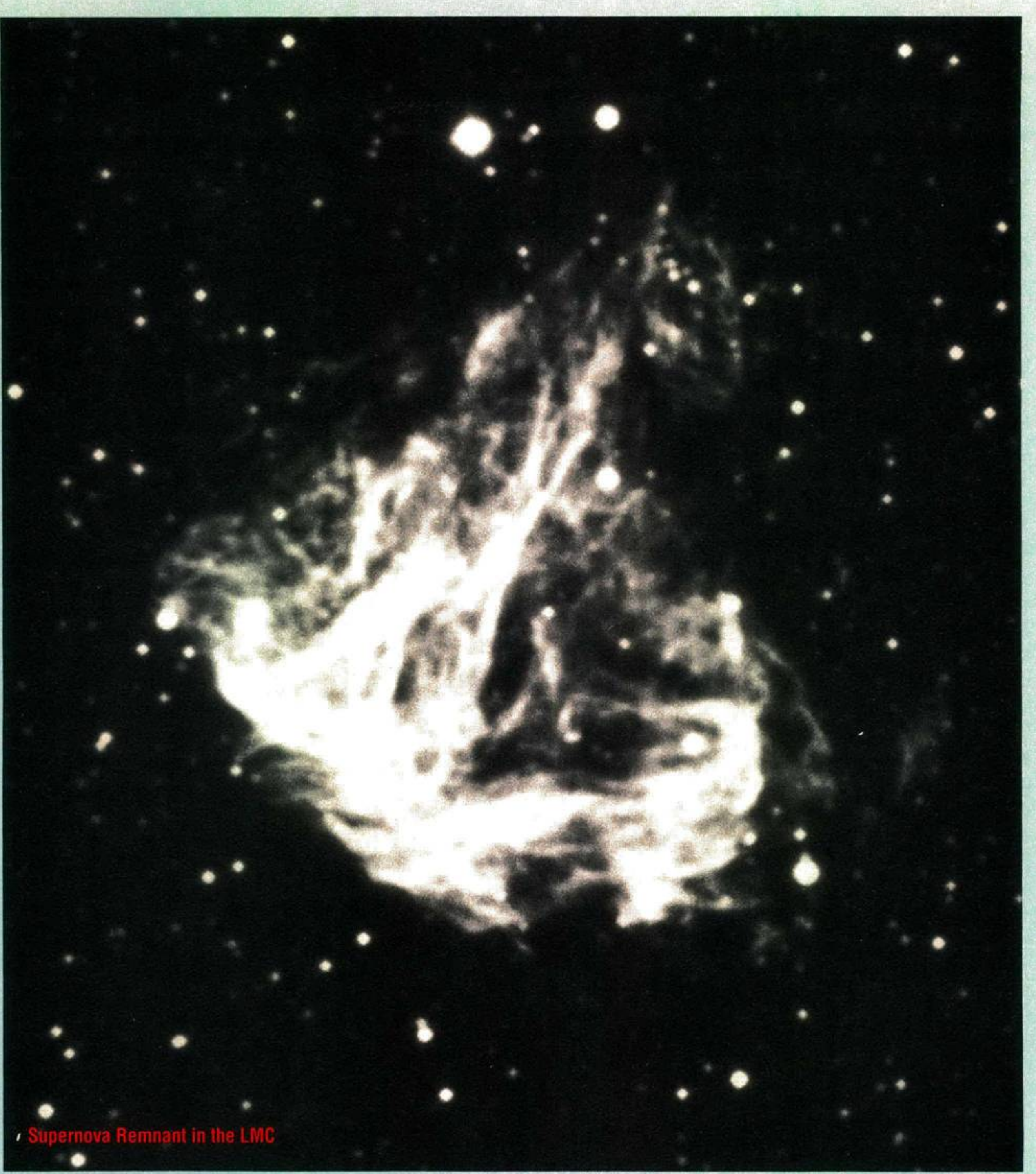


"Light Echo" around SN 1987A

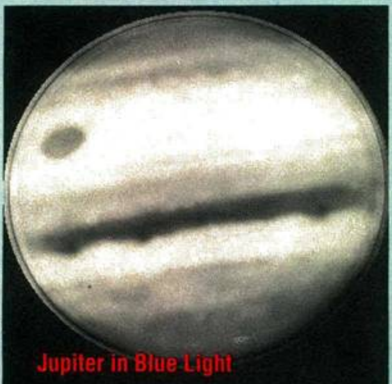
Astride a ridge in the Andes Mountains of South America stands the world's sharpest ground-based telescope. It's called the New Technology Telescope (NTT). Although it's not the largest telescope on our planet, the NTT beats all other ground-based telescopes in the quality of its images. The pictures here, taken during the NTT's first year of operation, testify to the success of the European Southern Observatory's approach to building its latest telescope.

The secret of the NTT's success is innovative technology. Superb optics, an ultraprecise mounting, and a dome unlike any other combine to give the NTT a significant edge over other ground-based telescopes. The NTT's main mirror rests on a computer-controlled support. Seventy-eight actuators in the mirror cell push and pull on the mirror to counteract flexure in the main mirror. They make the mirror three times more precise than the mirror of any other telescope of its size.

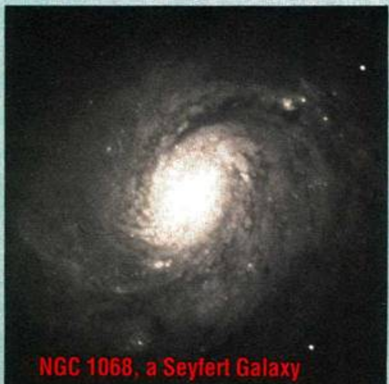
The 110-ton NTT telescope can be pointed with an accuracy of 1 arcsecond. Even during long photographic exposures the NTT tracks without smearing its



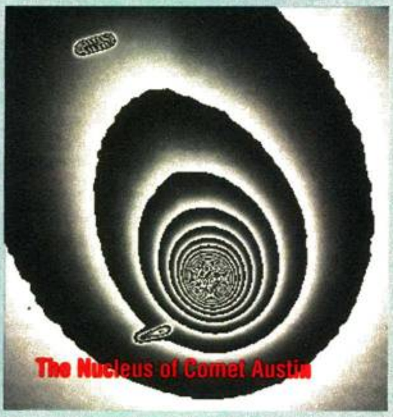
Supernova Remnant in the LMC



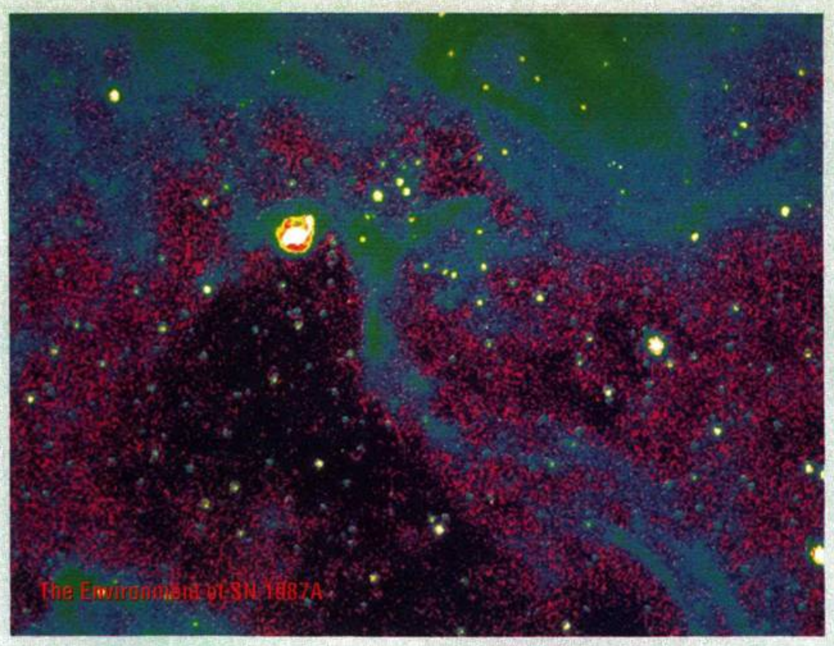
Jupiter in Blue Light

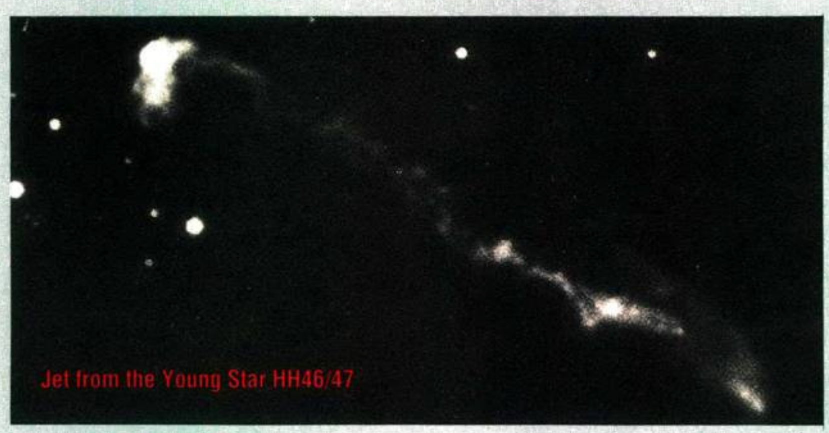


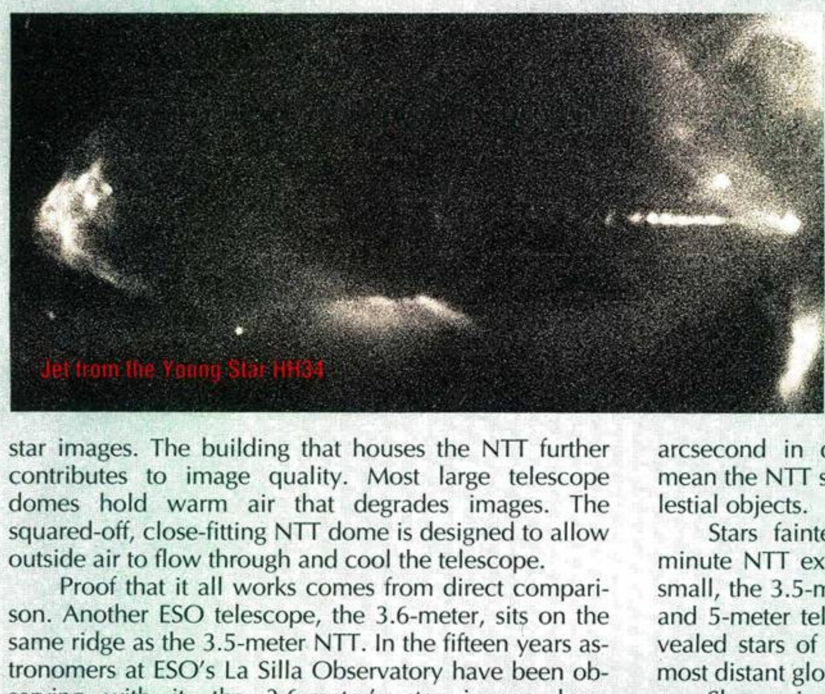
NGC 1068, a Seyfert Galaxy

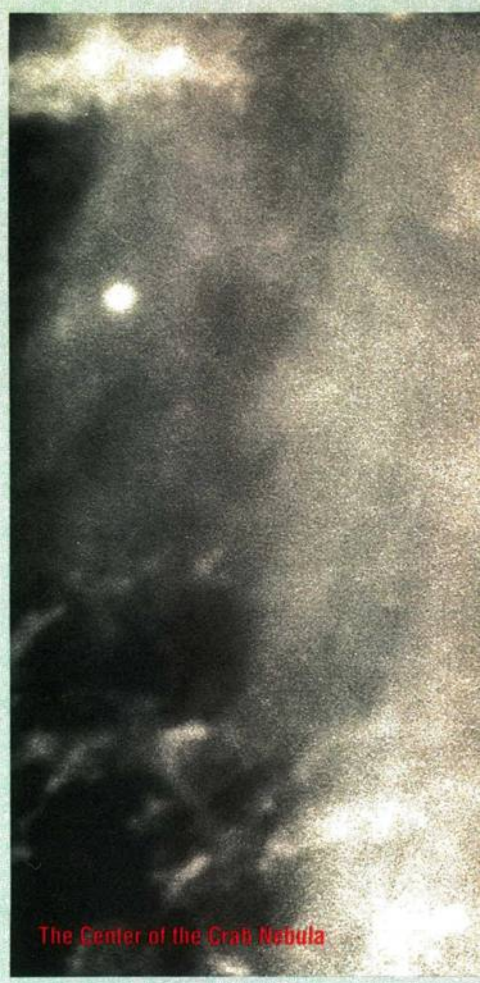


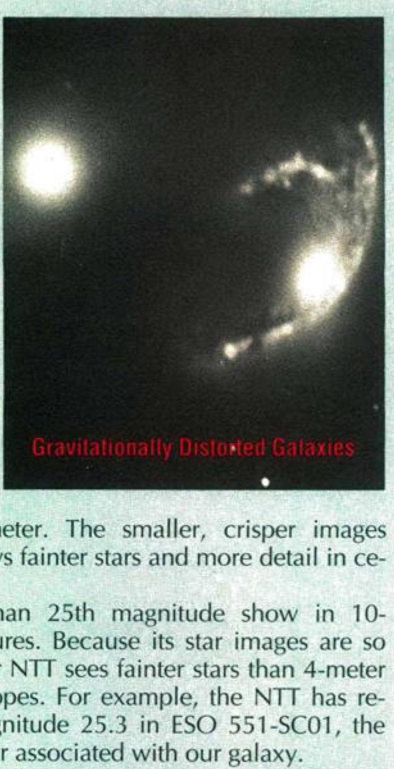
The Nucleus of Comet Austin


The Environment of SN 1987A


Jet from the Young Star HH46/47


Jet from the Young Star HH34


The Center of the Crab Nebula

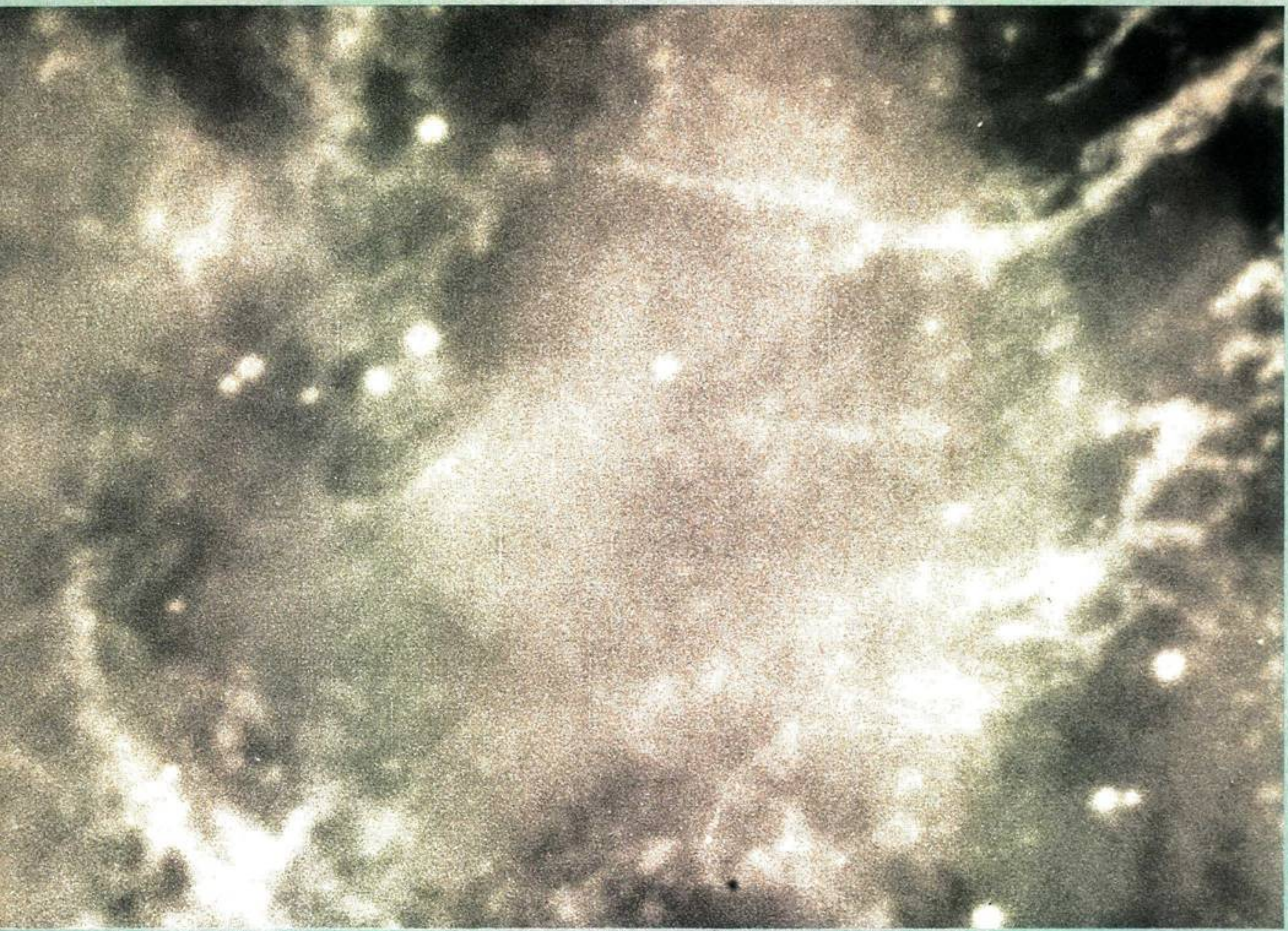

Gravitationally Distorted Galaxies

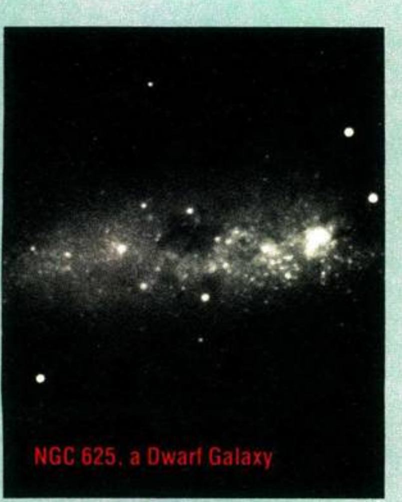
star images. The building that houses the NTT further contributes to image quality. Most large telescope domes hold warm air that degrades images. The squared-off, close-fitting NTT dome is designed to allow outside air to flow through and cool the telescope.

Proof that it all works comes from direct comparison. Another ESO telescope, the 3.6-meter, sits on the same ridge as the 3.5-meter NTT. In the fifteen years astronomers at ESO's La Silla Observatory have been observing with it, the 3.6-meter's star images have averaged 1 arcsecond in diameter. The NTT, on its first night in operation, showed images one-third of an arcsecond in diameter. The smaller, crisper images mean the NTT shows fainter stars and more detail in celestial objects.

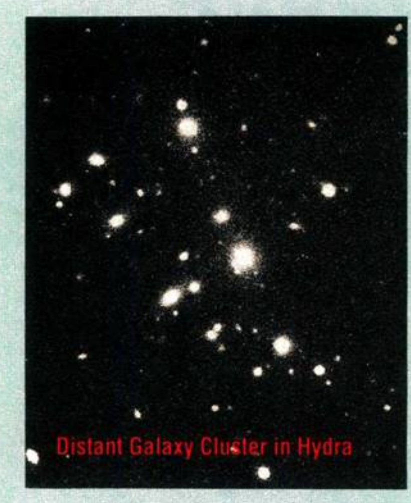
Stars fainter than 25th magnitude show in 10-minute NTT exposures. Because its star images are so small, the 3.5-meter NTT sees fainter stars than 4-meter and 5-meter telescopes. For example, the NTT has revealed stars of magnitude 25.3 in ESO 551-SC01, the most distant globular associated with our galaxy.

Sharper images allowed astronomers using the NTT to resolve the globular cluster 2 in the Fornax Dwarf galaxy to the core for the first time. This means that indi-

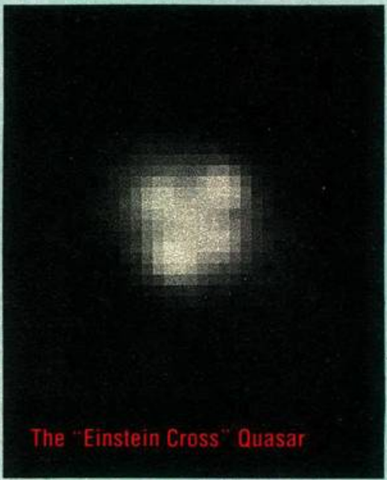




NGC 625, a Dwarf Galaxy



Distant Galaxy Cluster in Hydra



The "Einstein Cross" Quasar

vidual stars show all the way to the center in an image made on a night of excellent seeing. By graphing the brightness and colors of individual stars of the cluster on an H-R diagram, astronomers can now derive the cluster's age and distance.

Fine details in images of galaxies are important to astronomers. When they inventory the constituents of distant galaxies, astronomers must be able to distinguish nebulae from images of the brightest stars. In NTT images, stars stand out as points of light while nebulae appear fuzzy. With other telescopes stars and nebulae in distant galaxies both look fuzzy and astronomers can't tell which is which.

The sharpest views of the enigmatic object dubbed the "Einstein Cross" come from the NTT. Images show four points of light huddled around a dim central glow. The bright points are four gravitationally lensed images of a distant quasar. The central glow is light from an intervening galaxy. The galaxy's gravity bends the light of the quasar into four separate images.

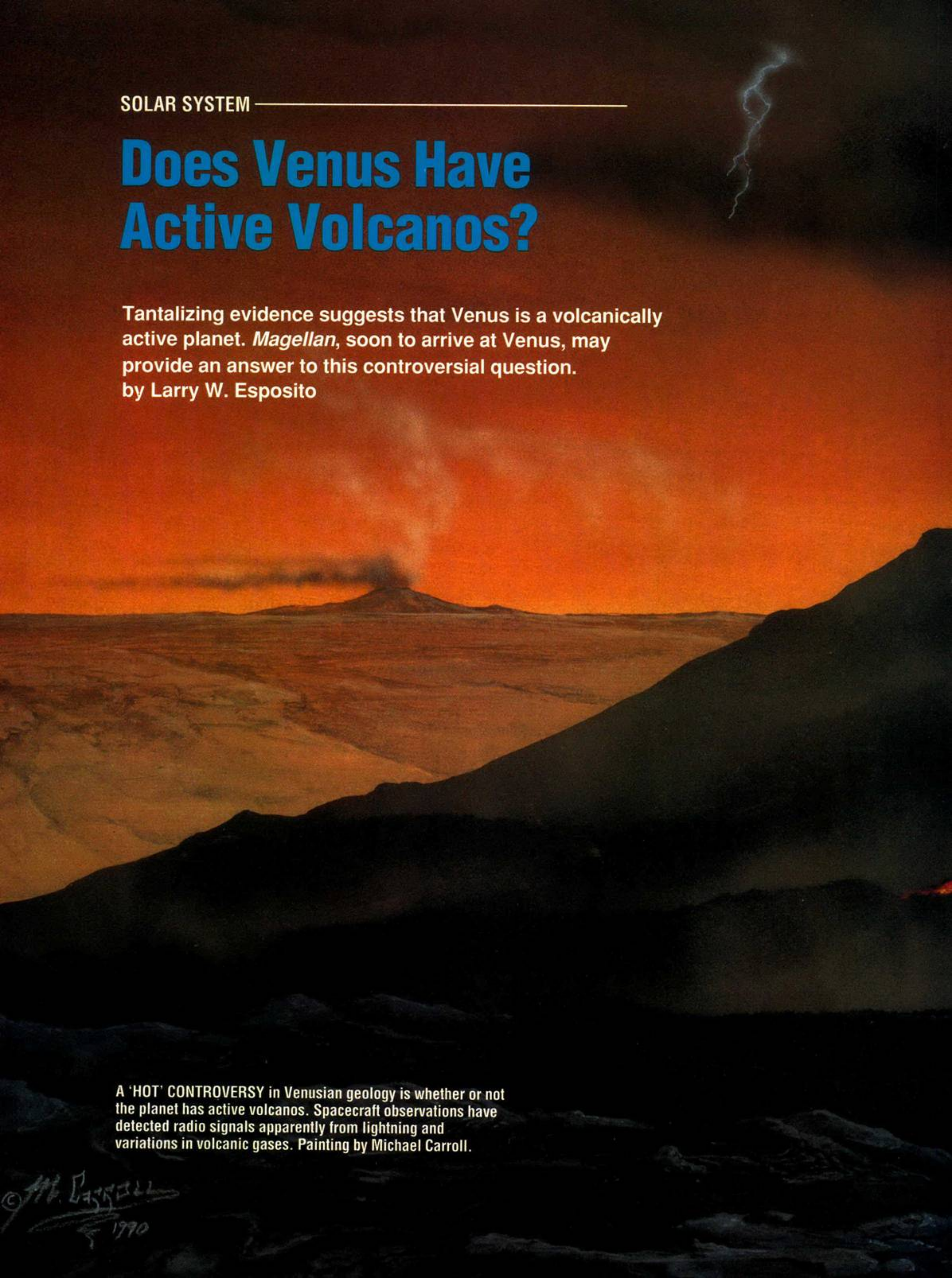
The pictures on these pages were taken during the NTT's first year of operation. They illustrate how much more ground-based telescopes can do than most astronomers could have imagined as little as a decade ago. ☐

SOLAR SYSTEM

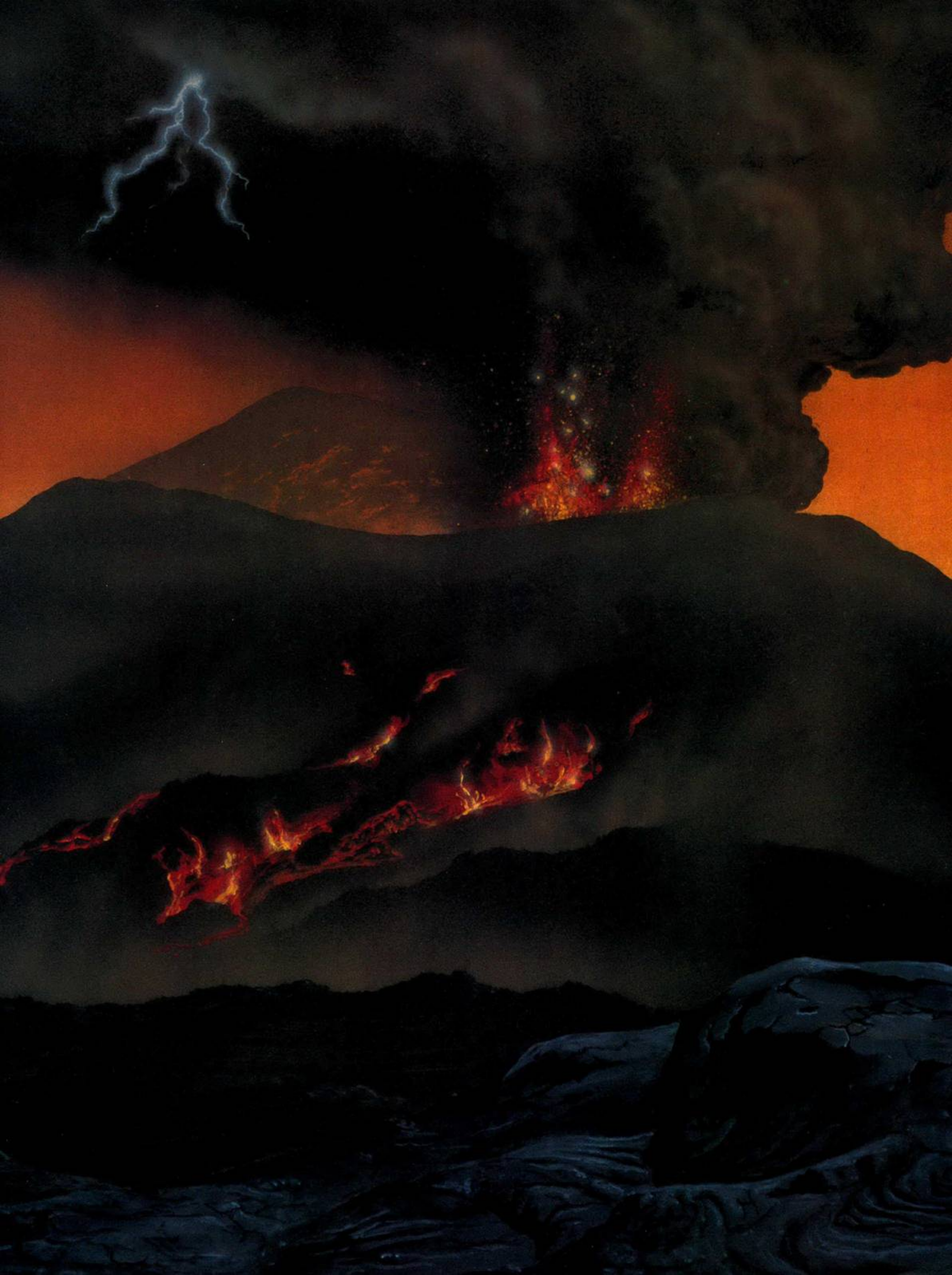
Does Venus Have Active Volcanos?

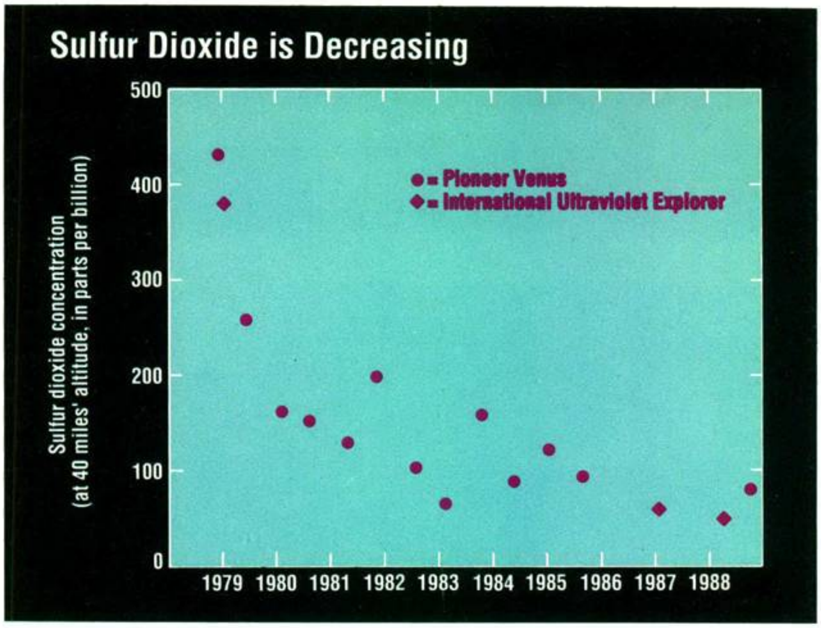
Tantalizing evidence suggests that Venus is a volcanically active planet. *Magellan*, soon to arrive at Venus, may provide an answer to this controversial question.

by Larry W. Esposito



A 'HOT' CONTROVERSY in Venusian geology is whether or not the planet has active volcanos. Spacecraft observations have detected radio signals apparently from lightning and variations in volcanic gases. Painting by Michael Carroll.




Sulfur Dioxide is Decreasing

The solar system is home to nearly seventy planets and moons. Of these, exactly three are known to have active volcanos: Jupiter's moon Io, Neptune's moon Triton, and our own Earth. Evidence is mounting, however, that Venus should also be admitted to this highly exclusive club. And that idea is the focus of considerable controversy regarding how closely Earth's geology parallels that of Venus.

The target of numerous successful U.S. and Soviet missions, Venus is the most visited celestial object, except for the Moon. As we await next month's arrival of the Magellan spacecraft to begin its detailed radar mapping, now is a good moment to examine the thorny question of Venusian volcanos. Does Venus have them, and if it does, have they been active recently?

To begin with, planetary scientists think Venus ought to have volcanos. It's the planet most like Earth, with a size, mass, and density all just slightly less than Earth's. (See "Venus: The Hellish Place Next Door," March 1990.) These facts alone would indicate a high probability of volcanism on the planet, but there's other evidence besides.

Radar mapping from Earth with the 1,000-foot Arecibo radio telescope and from spacecraft in orbit around Venus has depicted a surface with many distinctive volcanic landforms. Even the crude early radar images were good enough to reveal that a mountainous feature named Beta Regio, which lies near Venus' equator, looked like a massive volcano 450 miles across. Beta's size itself was a clue: it is bigger than the Hawaii volcano chain but smaller than Olympus Mons, the largest volcano on Mars.

When the Pioneer Venus spacecraft provided more detailed mapping from orbit, investigators suggested that the two biggest peaks making up Beta Regio — Rhea Mons and Theia Mons — could each be a giant volcano associated with a broad uplift and a north-south rift valley. (A similar situation occurs on Earth where the volcanic peak Mt. Kilimanjaro stands near the East African rift valley on the border of Tanzania and Kenya.)

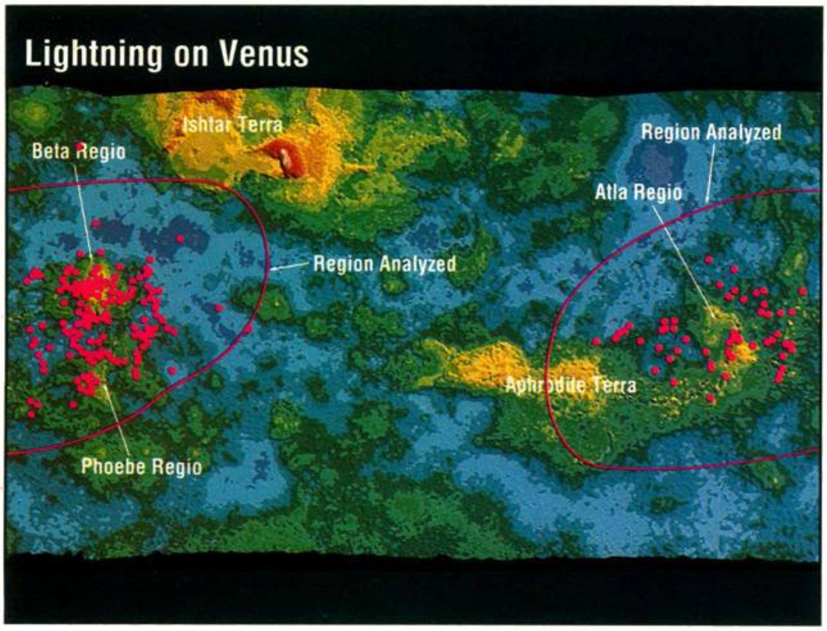
Rift valleys and volcanism go together. A rift valley on Earth is a very long, narrow depression bordered by two roughly parallel faults perhaps a dozen or so miles apart. Such a feature occurs where the grand tectonic forces from deep within the planet work to pull the surface crust apart. In themselves rift valleys are not volcanic, but because volcanic activities — lava flows and cinder cones — arise at points where the crust has been broken by the forces that create the valleys, a strong link exists between the two. It's reasonable to presume the same relationship holds true for Venus also.

In addition to the rift valley, high-resolution radar images from two Soviet spacecraft, *Venera 15* and *16*, showed numerous features that appear to be volcanic. These range from circular basins several hundred miles across created by the collapse of giant volcanos to fields of small conical structures, many surrounded with what look like lava flows. These structures closely resemble terrestrial volcanic cinder cones.

In short, there's ample evidence that Venus has a geologically volcanic surface: volcanos have erupted on Venus in the past, lava has flowed, and the surface has been locally crumpled. But however overwhelming the evidence of past volcanic activity, the data are not too helpful when it comes to answering the question of whether volcanos are active now.

One of the strongest pieces of evidence for recent volcanic activity comes from chemical measurements of the surface made by the Soviet *Venera* probes. The amounts of calcium and sulfur in the surface rocks are not in chemical equilibrium with the amount of sulfurous gases (mostly sulfur dioxide) measured in the atmosphere. This means there is an extra amount of these atmospheric elements that has not yet chemically combined with the rocks, a process that should occur rapidly on a geologic time scale.

The fact that the surface is out of chemical equilibrium with the atmosphere shows clearly that some part of the picture has to be geologically recent — either the rocks or the sulfurous gases in the atmosphere. Laboratory studies by Bruce Fegley and Ronald Prinn of MIT show that all the sulfur dioxide now in the Venusian atmosphere — equal to 1/10,000 of Venus' total atmosphere — would be absorbed or otherwise lost in less than 2 million years. Volcanos could both provide new rock at the surface *and* inject sulfurous gases into the atmosphere, and probably did both.



A MARKED DECLINE of sulfur dioxide in Venus' upper atmosphere has continued since measurements began in late 1978 (far left). During the same period, lightning was active over Beta, Phoebe, and Atla Regios (left). Both sets of observations suggest intermittent volcanic eruptions.

One thing, however, is pretty clear from the lack of chemical equilibrium: volcanos have erupted on Venus in the last million years. That's a useful fact to keep in mind. But a million years ago is a long way from today, at least in human terms. So the question really comes down to this: Is there any evidence that Venus is volcanic on a time scale where "recent" means a decade or so? The answer is yes, but the evidence is not clear-cut.

In 1978 the *Venera 11* and *12* landers detected electromagnetic signals that seemed to come from lightning propagating at low altitudes. The craft also detected sounds that may have been booms of thunder. Also, over a period that extended from 1978 to 1983, the electric field detector on the *Pioneer Venus* orbiter detected on hundreds of occasions radio bursts that could have been emitted by lightning. These radio bursts appeared to cluster around the Beta and Atla regions, areas with topography strongly reminiscent of terrestrial volcanos.

Volcanic activity and lightning are linked because as hot plumes of volcanic gases shoot up into the atmosphere, dust, ash, and debris begin to separate into regions of opposite electrical charge, aided by the churning of the cloud. When this happens the eruption cloud behaves much like a terrestrial thunderstorm. Although the charge separation process is not understood in detail, even on Earth, scientists know that the regions of opposed charges continue to grow in strength as the cloud is fed by strong updrafts and fresh material. When the electric differential between separate parts of the cloud grows strong enough to break through the natural insulation of the dust — *flash, BAM!* — a bolt of lightning releases the pent-up charge.

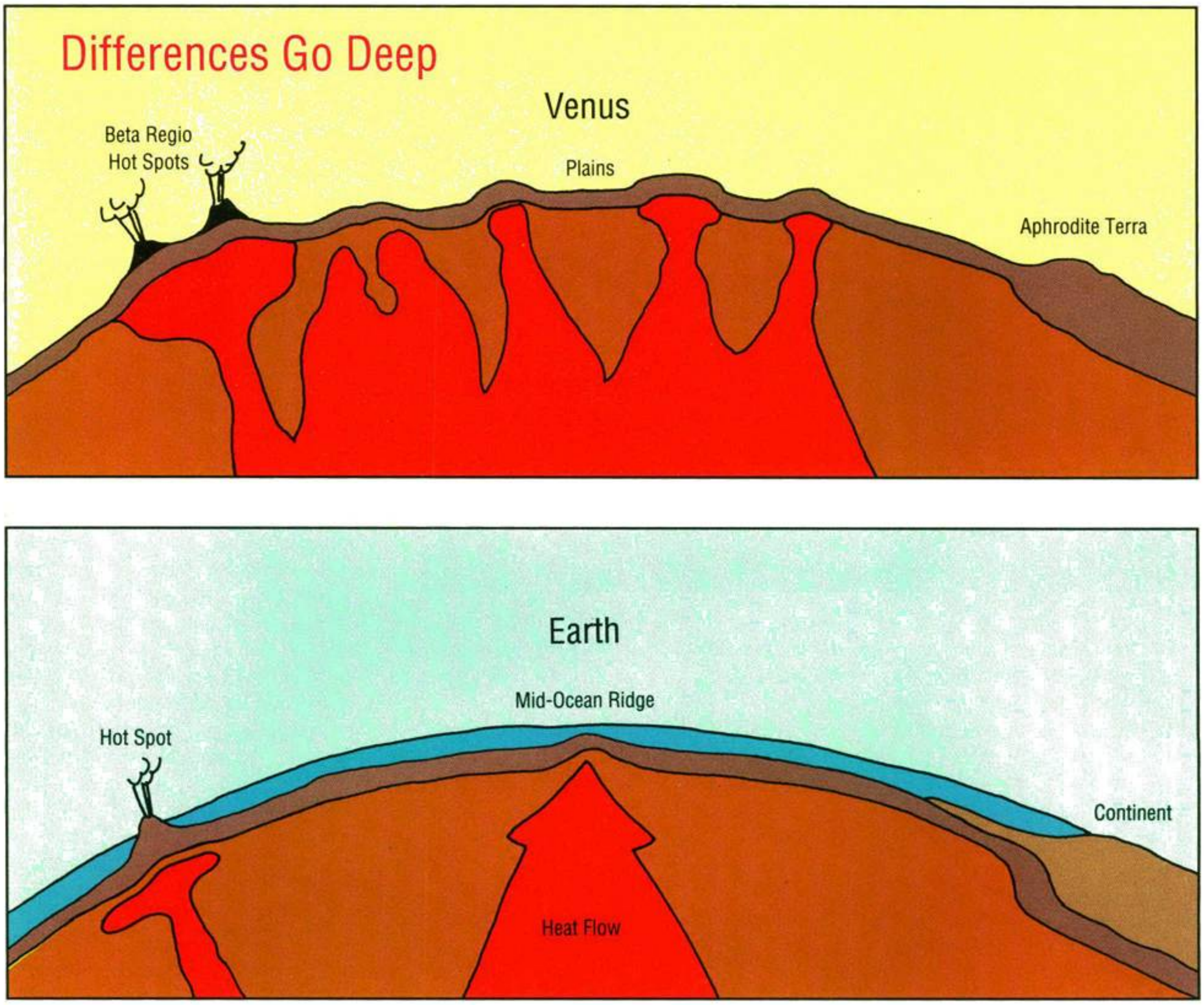
Evidence for recent eruptions also comes from observations of the chemical composition of Venusian clouds made by the *Pioneer Venus* orbiter during the last decade. On Earth major eruptions (such as that of El Chichón in 1982) inject haze particles and sulfurous gases high into the stratosphere where they may linger for months or years, drifting slowly around the planet many times. On Venus a similar phenomenon has been observed. In late 1978 *Pioneer Venus* scanned the upper Venusian atmosphere and found a concentration of sulfur dioxide gas that was ten to a hundred times greater than the highest upper limit set by Earth-based observations during the previous decade. During that period Venus had become greatly enriched in sulfur dioxide. Furthermore, *Pioneer Venus* detected a haze of small particles covering the entire planet, with the poles especially hazy and unusually bright. Investigators noted both these occurrences at the time but didn't make a connection with volcanos.

Pioneer Venus has continued to monitor these constituents above the clouds. Over the years a remarkable discovery has emerged: both the sulfur dioxide and the haze have been gradually disappearing. By now only about 10 percent of the 1978 amount remains. This disappearance has also been confirmed by measurements taken by the Earth-orbiting *International Ultraviolet Explorer* between 1979 and 1987 and by other Earth-based observations. The haze and the sulfur dioxide are now approaching their pre-1978 values. Analysis of recent Earth-based radio observations by Paul Steffes and his collaborators show less sulfur dioxide below the clouds than was measured by *Pioneer Venus* and the *Venera* landers, which is also consistent with the decrease in sulfur dioxide. Inconclusive Earth-based data show that a similar phenomenon may also have occurred in the late 1950s.

The best explanation right now for the decrease is that from time to time major volcanic eruptions inject sulfur dioxide gas to high altitudes. The haze comes from particles of sulfuric acid, which is created by the action of sunlight on the sulfur dioxide (the same reaction that creates acid rain on Earth). Being heavy the haze particles gradually fall out of the upper atmosphere, letting conditions up there return to normal between eruptions.

My calculations show that this eruption of the late 1970s was at least as large as the 1883 explosion of Krakatoa. That explosion — equal to a 500 megaton H-bomb — was the most violent of the last century or so, shooting vast quantities of gas into Earth's stratosphere. (By comparison, the 1980 Mount St. Helens eruption was less than a tenth as powerful as Krakatoa.)

How common are such eruptions likely to be on Venus? And how volcanically active is the planet as a



whole? We tend to think of geology as being largely static. The heavily cratered parts of the Moon, Mars, and Mercury are all more than 4 billion years old. Their ancient landscapes have remained little changed since shortly after the formation of the solar system. By contrast the average age of Earth's surface is only 250 million years. In part this is due to the effects of wind and water wearing away the surface, but an even bigger agent of change is the ceaseless movement of Earth's continents driven by plate tectonics.

Careful study of the radar images of Venus has revealed no global tectonic system like Earth's. Therefore the volcanos on Venus are probably not like those of the Pacific-girdling "chain of fire," such as Mount St. Helens. Instead, the volcanos of Venus could be more like the Hawaiian volcanos or Mars' Olympus Mons, neither of which occurs at the boundary of a plate. Geologists think these isolated volcanos form over "hot spots," locations where the heat of the planet's interior melts and thins the crust above them, providing both a source of molten lava and an easy conduit through which it can reach the surface.

The intensity of Venusian volcanic activity is important to understand, but how often volcanos erupt is nearly unknown. On Earth, plate tectonics provides a mechanism to remove most of the heat generated by Earth's radioactive material. This mechanism does not appear to operate very much on Venus, but calculations suggest that individual volcanic eruptions over hot spots could transport most of the heat created by Venus' complement of radioactive materials. A scenario along these lines has been developed by Donald Turcotte of Cornell University. His calculations show that approximately a thousand Hawaii-style hot spots would be required. Together these would produce about 50 cubic miles of new Venusian crust every year, about ten times what is produced yearly from Earth's mid-ocean ridges.

The problem with this amount of activity is that it would soon cover much of Venus' surface and eradicate the ancient craters seen in the radar images. The total number of these craters has convinced Soviet scientists that the average age of Venus' surface is older than 200 million years, which conflicts with the level of activity Turcotte proposed. On the other hand, the amount of volcanism implied by the experiments of Bruce Fegley and Ronald Prinn of MIT (based on the lack of chemical equilibrium) is ten to a hundred times less than Turcotte's model demands. This fits well with the age of the surface determined by the Soviet *Venera* missions.

A compromise seems to be the best way to reconcile the measurements with the theory. Venus' surface is likely much younger than the Moon's; volcanic activity

DIFFERENT PLANETS, DIFFERENT tectonic styles. Venus probably has a greater number of "hot spots" (volcanic plumes rising from the mantle) than Earth does, but it appears to lack Earth's mid-ocean ridge system. This may reflect a radically different crustal structure.

has erased most of its older features. Moreover, eruptions in the last million years have probably occurred. However, volcanos can't get rid of all of Venus' internal heat, so some kind of plate tectonics must be occurring, even if only on a small scale.

Taken together the evidence from space missions points to a Venus that is certainly active but not as much as Earth. Much more controversial, however, is the question of whether volcanos have erupted in recent times. The case for it is based only on indirect evidence.

Three main objections have been raised against the idea of present-day volcanism. The first says that the lightning results are flawed. The second, that meteorological phenomena probably explain the sulfur dioxide changes. Lastly, theoretical calculations show that explosive volcanism (to blow the gas into the upper atmosphere) should be rare on Venus. Let's see how valid these objections are.

The lightning. Some researchers claim that the signals observed by the *Pioneer Venus* orbiter were phenomena near the spacecraft and unrelated to Venus' surface. But an analysis of the signals by Chris Russell of UCLA shows that they are similar to radio waves called whistlers that are produced by lightning on Earth. Unfortunately, Russell's work does not yield a strong correlation of these signals with the volcanic structures on Venus. Therefore, their relation to any volcanism is unclear.

The sulfur dioxide variations. There is no known meteorological mechanism that could collect and transport the sulfur dioxide observed by *Pioneer Venus* to the high altitudes above the clouds where it was seen. Measurements of possible updrafts by the Soviet *Vega* balloons showed that this mechanism also is insufficient to lift the gas above the clouds. Further, no meteorological explanation accounts for why such sulfur dioxide injections are separated by decades. The volcanic eruption explanation, on the other hand, is straightforward, using the heat of the eruption to lift the volcanic gases through the stable layer below the clouds. Another point in its favor is that this mechanism has been observed on Earth. However, these arguments neither prove the volcanic hypothesis nor disprove the meteorological explanation.

The explosive eruptions. James Head of Brown University and Lionel Wilson of the University of Lancaster have studied the mechanisms of volcanic eruptions. They conclude that explosive eruptions are less likely on Venus than on Earth because of Venus' higher temperature and pressure. The lava in an explosive eruption would have to contain more than 4 percent volatile materials such as water or carbon dioxide, which they consider highly unlikely. Therefore, they feel such eruptions must be quite rare. On the other hand, Aleksandr Bazilevsky of the Vernadsky Institute in Moscow argues that the sequence of small dome-shaped hills seen in the Soviet radar images implies the presence of these volatiles in the lava. The question is unresolved, but in any case the observations may indicate that more volatile-rich rocks exist deeper in the Venusian crust.

I hope no one gets the idea that the question of Venus' volcanism is settled! In this important but controversial research, many of the pieces of evidence are indirect and the images of Venus available now are not sharp enough to decide the issue. The Soviet images show no evidence for present volcanism, but they would not be clear enough to reveal volcanism on Earth either. We are hoping that *Magellan* will resolve the question with its greater global coverage and higher resolution.

Magellan will allow a much better characterization of the geological processes that have been active on Venus. This will solve the question of where Venusian tectonics is active now and will help us define the evolution of the planet. It will also tell us where individual features come from and determine the age and type of eruption that created them. The images will provide age estimates for much of the surface and perhaps very young volcanic flows will be evident.

I'll leave you with an exciting possibility: we might even catch an eruption "live." During a possible extended mission, *Magellan* will map the Venus surface a second time. If any volcano has erupted between the two observing runs, we might be able to spot the changes. This is no fantasy. If *Magellan* were orbiting Earth, its radar has good enough resolution to show that the top of Mount St. Helens has been missing since 1980. Let's hope we get lucky!

Larry W. Esposito is an associate professor at the University of Colorado at Boulder and a member of the ultraviolet spectrometer team on the Pioneer Venus *orbiter.* □

TRAILBLAZERS OF ASTRONOMY

The Industrious Mrs. Fleming

Nearly forgotten today, Williamina Fleming was the greatest woman astronomer of her time.

by Joseph L. Spradley

In the age of steam and smoke, iron gears and railroads, astronomy too was picking up steam. By 1880 photography and spectroscopy had begun to revolutionize the study of the heavens. However, the supply of new data produced by the nation's observatories far exceeded the manpower needed to analyze and interpret the information. Astronomers needed efficient, capable assistance and plenty of it.

Like most astronomers of the day, Edward C. Pickering, as director of the Harvard College Observatory, was struggling with this problem. And Pickering was not known for his patience. One day as he was supervising his staff, Pickering snapped at a sluggish assistant, saying his Scottish housemaid could do a better job of organizing and classifying spectra. The idea apparently stuck. Williamina Fleming, Pickering's one-time housekeeper, joined the staff of the observatory and went on to become one of the greatest astronomers of her day. In addition to her diligence, keen eyesight, and remarkable memory, she was also a highly capable administrator. Though sparkling and friendly, Fleming was regarded with awe by the many young women who served as computers under her direction.

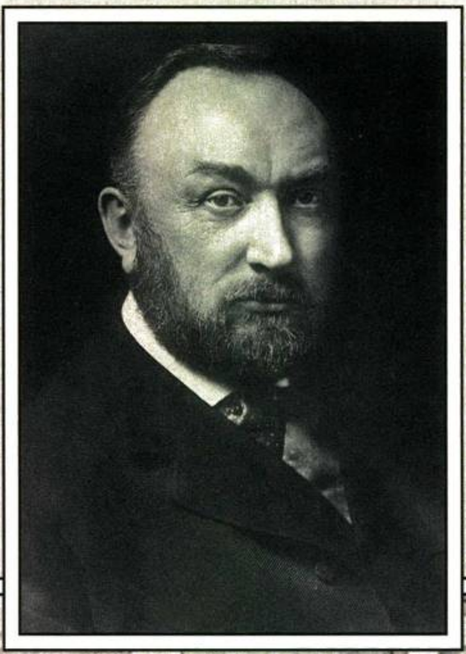
Fleming's success came slowly, however. When the Draper catalog of stellar spectra was published one hundred years ago, only a careful reader would have recognized that this pioneering work was the product of a young woman known as Mina Fleming. The Draper catalog was the first in a series of monumental efforts at Harvard to classify the varied arrangements of lines and bands in stellar spectra. For several years her work at the Harvard College Observatory was published in the customary way, under the name of director Pickering. But by 1890 the signature "M. Fleming" began to appear with Pickering's own reports in astronomical journals. On the second page of the Draper catalog Pickering acknowledged that "the greater portion of this work, the measurement and classification of spectra, and the preparation of the catalogue for publication, has been in the charge of Mrs. M. Fleming."

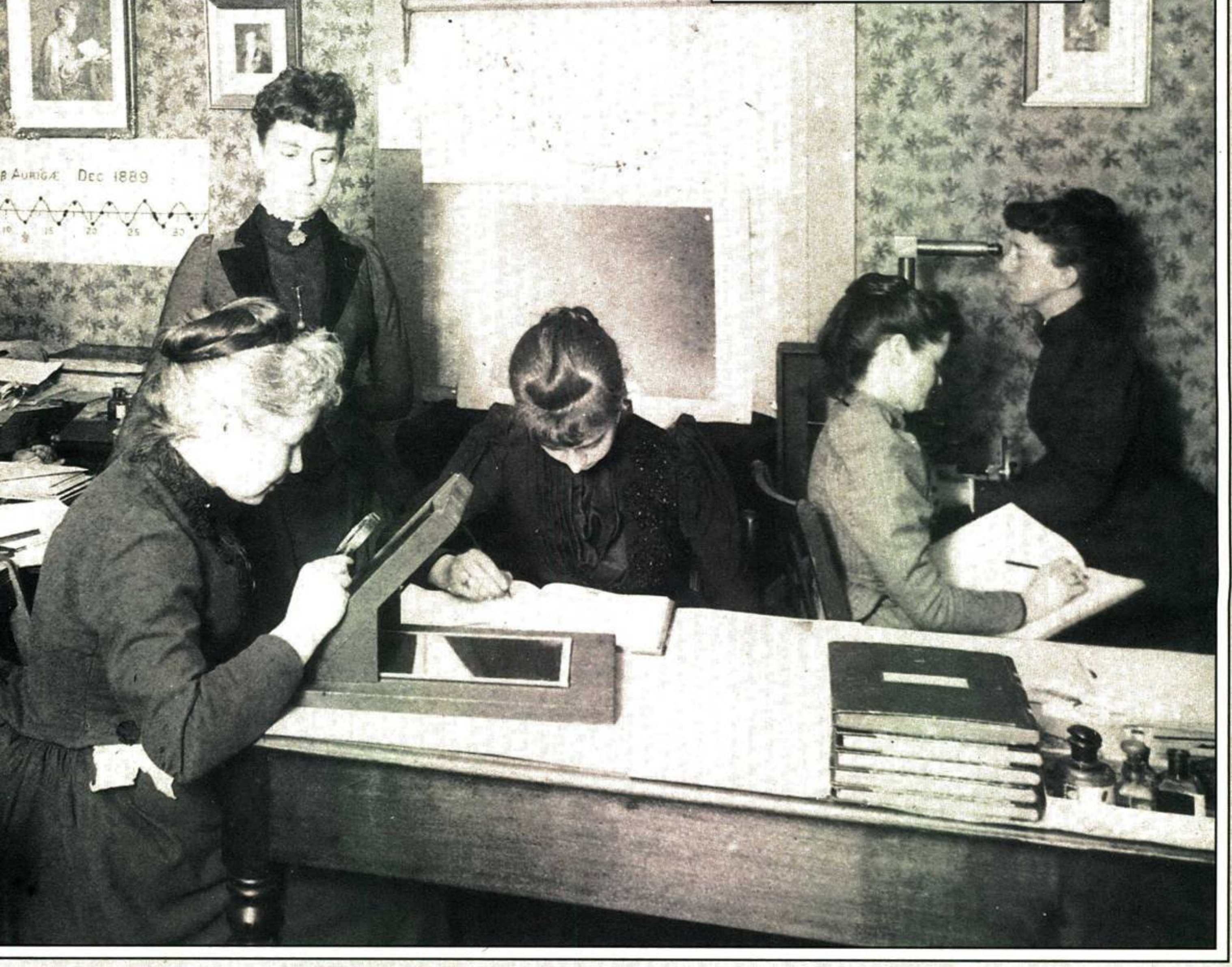
Fleming's contributions to the Draper catalog were astonishing. She examined 633 photographic plates containing spectra of about 100 stars each. She measured the brightness and wavelengths of the lines in 28,266 spectra. She selected over 10,000 of these spectra with sufficient brightness and clarity and classified them into fifteen categories according to the complexity of their lines and bands. She also supervised a staff of women who calculated the positions of each star and she also directed the preparation of the catalog for publication.

In the end the catalog contained spectral classifications for 10,351 stars. A reviewer in the English journal *The Observatory* wrote: "The name of Mrs. Fleming is already known to the world as that of a brilliant discoverer, but the present volume shows that she can do real hard work as well." Few would have guessed that she began her career after serving as a single-parent housekeeper for the Pickerings.

Williamina Paton Stevens was born in Dundee,

WOMEN COMPUTERS, directed by Williamina Fleming (below, standing; and inset at left), thrust astronomy forward at Harvard in the 1890s. The observatory director was Edward C. Pickering (right). All photos courtesy Harvard College Observatory.





FLEMING'S FOLLOWERS included Annie Jump Cannon (right), Henrietta Swan Leavitt (below, right), and Cecilia Payne-Gaposchkin. Each made monumental contributions to stellar cataloging and astrophysics. Photos courtesy Harvard College Observatory except Payne-Gaposchkin, courtesy Katherine Haramundanis.

Scotland, on May 15, 1857, the daughter of Robert and Mary Stevens. Her father was an accomplished craftsman who specialized in carving and gilding and was among the first in Dundee to experiment with the new daguerreotype photographic process. Hard luck struck the family in 1864, however, when Robert died. By the time Mina turned fourteen, she was forced to become a student teacher to help support the family. After five years of teaching she married James Orr Fleming and in 1877 they immigrated to Boston. After two years the marriage failed. To support herself and the child she was expecting, Mina took a job as second maid in the Pickering household. A few months later she took a short leave to return to Scotland for the birth of her son.

Under Pickering's directorship Harvard College Observatory employed women as research assistants. After the death of the previous director, Joseph Winlock, his daughter Anna Winlock became the first paid female staff member, working for the rest of her life at the observatory. Mina Fleming joined the staff in 1881 at Pickering's invitation, even though she had no formal training in astronomy. For the next thirty years she worked closely with Pickering, first in clerical and computing work but steadily taking on more advanced duties.

Fleming's chief long-term assignment was the classification of stars on the basis of the various patterns of lines and bands that appeared in photographs of their spectra. Photographic plates proved to be more sensitive than the human eye, revealing new features that required a more complex classification scheme than the one previously used by Pickering. In preparing the Draper catalog, Fleming used 633 photographic plates taken with the 8-inch f/5.5 Bache telescope, which was fitted with a prism. In the "Pickering-Fleming system" the spectra were organized into fifteen categories using most of the letters from A to Q, according to the complexity of their lines and bands. But about 99 percent of the stars were in the six classes A, B, F, G, K, and M. This system was later refined by Annie Cannon at Harvard and is still in use by professional astronomers.

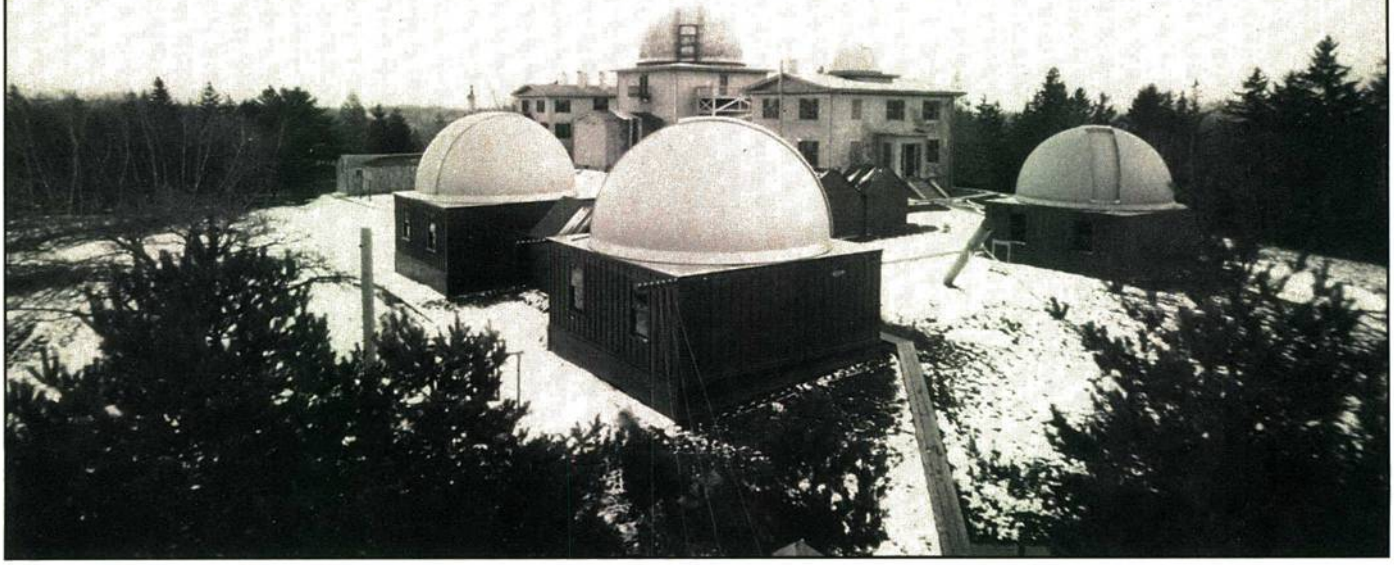
In the course of her work Fleming found the spectra of many ruddy variable stars of spectral type M contained bright emission lines in addition to the usual dark absorption lines. Her investigation showed that all such stars vary in their luminosity, providing a new tool for discovering long-period variables. Using this technique she discovered 222 variable stars. In her 1907 paper "A Photographic Study of Variable Stars," she gave the variation in brightness of each star based on a selected list of companion stars. This achievement led the British astronomer H. H. Turner to comment that "many astronomers are deservedly proud to have discovered one variable, and content to leave the arrangements for its observation to others; the discovery of 222, and the care of their future on this scale, is an achievement bordering on the marvelous."

In addition to her work on variable stars Fleming made a special study of other stars with peculiar spectra. This led her to the discovery of ten novae, more than one-third of the twenty-eight novae known at the time of her death. She also discovered 94 of the 107 known Wolf-Rayet stars characterized by broad emission lines. Shortly after she died, her list of "Stars Having Peculiar Spectra" was published in the *Annals* of the Harvard College Observatory.

Fleming's diligence and research ability was combined with effective administrative skill in her supervision of several dozen young women who worked under her. Though she was warm and friendly, her reputation was that of a strict disciplinarian. She served as editor of all the publications issued by Harvard College Observatory. In 1898 she was appointed by the Harvard Corporation as curator of astronomical photographs. Under her supervision nearly 200,000 photographic plates taken at Harvard and in Arequipa, Peru, from 1882 to 1910 were examined and cataloged.

In 1906 she became the first American woman to be elected to the Royal Astronomical Society. Although she worked long hours and rarely missed a day of work, she boasted of being a good cook and enjoyed Harvard football games. Despite recurring illness in her later years, Fleming traveled to an astronomical meeting at Mount Wilson, California, in the autumn of 1910. The following spring she became ill with pneumonia and died in Boston at the age of fifty-four.

Even after her death Fleming's influence guided her assistants as well as others who hadn't even known her. Henrietta Swan Leavitt continued Fleming's study of variable stars at Harvard as a research assistant after her graduation from Radcliffe College in 1895. At the age of thirty-four she received a permanent position and advanced rapidly to become chief of the photometry department. She discovered four novae and more than 2,000 variable stars. In 1912 Leavitt announced her dis-



HARVARD COLLEGE OBSERVATORY consisted of eight small buildings when women first joined the staff in the early 1880s. When observatory staff members posed for a photo in 1917, twelve women posed with only two men. Included in the photo are Leavitt (sixth from left) and Cannon (fifth from right). Photos courtesy Harvard College Observatory.

covery that the luminosity of Cepheid variable stars in the Magellanic Clouds was related to the period of their brightness variation. Harlow Shapley used this law to find the distances of such stars by using their period to find their absolute magnitudes and comparing that with their apparent magnitudes. This period-luminosity relationship became an essential tool for measuring the size of the Milky Way and the distances to other galaxies.

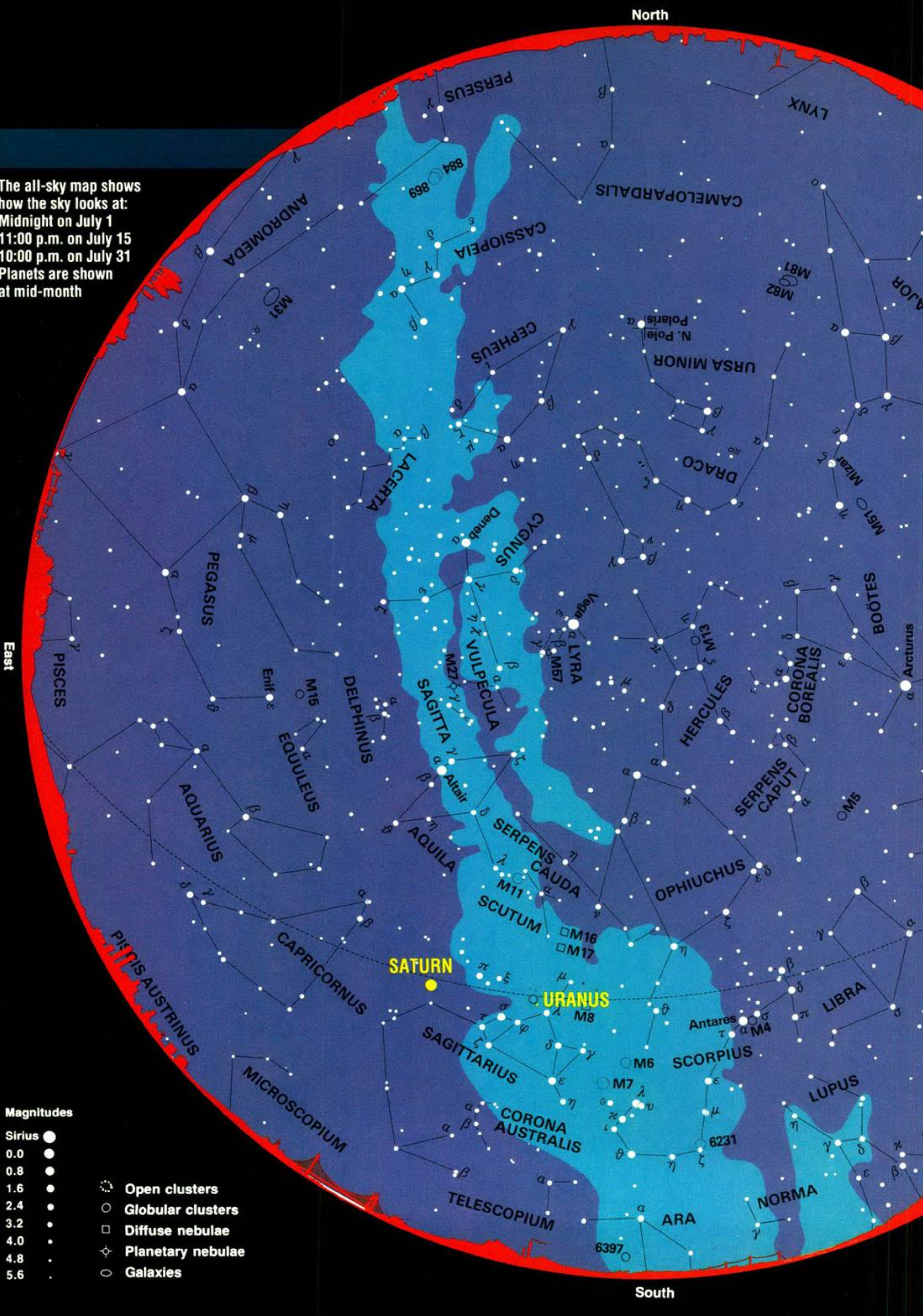
Annie Jump Cannon is best known for her development of the definitive Harvard system of spectral classification based on the earlier work of Fleming. She graduated from Wellesley College in 1884 and joined the Harvard staff at the age of thirty-three in 1896. In her early work she discovered five novae and more than three hundred variable stars from their spectral peculiarities. In 1911 she succeeded Fleming as curator of astronomical photographs. Cannon completed her major publication, the Henry Draper catalog, in 1924. It contains spectral classifications for 225,300 stars. This was increased to a total of 350,000 stars in her later publications. Cannon's work provided the basis for future research in stellar statistics and astrophysics, leading to our modern understanding of stellar structure and evolution.

The most important theoretical interpretation of the spectral classifications developed by Fleming and Cannon was achieved by Cecilia Payne-Gaposchkin. After graduating from Cambridge University in 1923, Payne-Gaposchkin joined Harvard College Observatory at the invitation of Harlow Shapley. Her doctoral thesis on stellar atmospheres, published in 1925 when she was twenty-five years old, was the first dissertation completed at the observatory. In it she derived the first spectroscopic temperature scale for stars and applied it to hundreds of Harvard photographs. From this she calculated temperatures for each spectral type and demonstrated that Cannon's order of classification (OBAFGKM) was directly related to temperature, from above 20,000 kelvins for type "O" to about 3000 kelvins for type "M". Thus she showed that apparent spectral differences arise primarily from variations in temperature and density rather than from differing chemical compositions. In 1932 Payne-Gaposchkin identified the atoms and ions responsible for the bright emission lines in the spectra of Wolf-Rayet stars.

Williamina Fleming was an important pioneer in stellar spectroscopy. Her efforts in spectral classification led to the discovery of many unusual stars and laid the groundwork for some of the most important developments in stellar astronomy. In the century since she published the Draper catalog of stellar spectra, Fleming's work has been the foundation for much of our knowledge about the evolution of stars and the structure of the universe. Though she is little remembered today, Williamina Fleming reached out and touched the universe as few people in history have. ☐

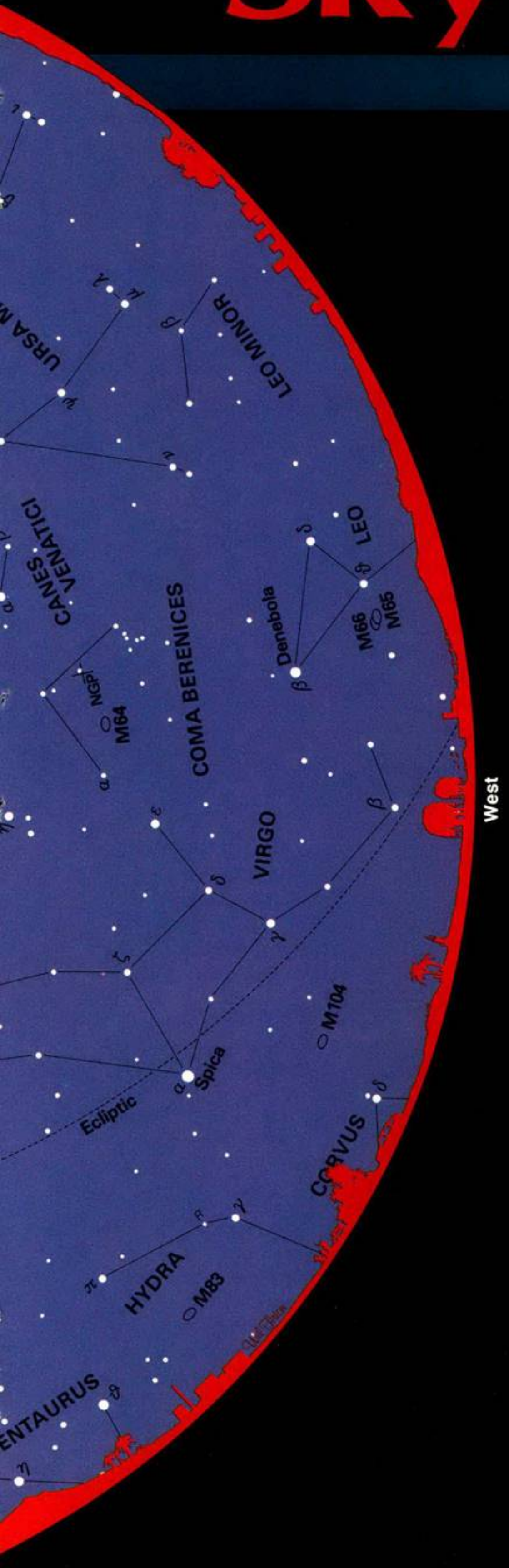
Joseph L. Spradley is a professor of physics at Wheaton College in Wheaton, Illinois.

The all-sky map shows how the sky looks at:
Midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31
Planets are shown at mid-month


North
South
East
PERSEUS
LYNX
CAMELOPARDALIS
ANDROMEDA
CASSIOPEIA
869
884
M31
M81
M82
CEPHEUS
N. Pole
Polaris
URSA MINOR
LACERTA
DRACO
Mizar
M51
PEGASUS
Deneb
CYGNUS
Vega
LYRA
M57
BOÖTES
Arcturus
PISCES
Enif
M15
DELPHINUS
M27
VULPECULA
SAGITTA
M13
HERCULES
CORONA BOREALIS
EQUULEUS
Altair
SERPENS CAPUT
M5
AQUARIUS
AQUILA
SERPENS CAUDA
OPHIUCHUS
M11
SCUTUM
M16
M17
CAPRICORNUS
SATURN
URANUS
M8
Antares
M4
LIBRA
PISCIS AUSTRINUS
SAGITTARIUS
M6
SCORPIUS
M7
LUPUS
MICROSCOPIUM
CORONA AUSTRALIS
6231
TELESCOPIUM
ARA
NORMA
6397
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

July 1990



SOLAR ECLIPSE ON JULY 21/22

Viewers in the northwestern United States and western Canada will be treated to a partial eclipse of the Sun in the late afternoon hours of July 21. In the Eastern Hemisphere, where it will be July 22, the Sun is completely eclipsed in a narrow band that runs through Finland and the northern Soviet Union.

SATURN AT OPPOSITION

Saturn reaches opposition on July 14 and is at its best for 1990 throughout the month. The ringed planet shines at magnitude 0.1 this month, its brightest for the year, and is visible all night.

VENUS AND TWO CLUSTERS

When July begins, Venus lies between the Pleiades and Hyades star clusters in the constellation Taurus. The attractive trio of objects is located low in the east-northeast shortly before dawn.

DELTA AQUARIDS PEAK ON JULY 28/29

The Delta Aquarid meteor shower peaks this year on the night of July 28/29. You should see ten to thirty meteors per hour after midnight that night, but the shower's peak is so broad that significant numbers of meteors are visible for several days before and after.

Calendar of Events

2 Mercury is in superior conjunction

3 Venus passes 4° north of Aldebaran, 11 a.m. EDT

The Moon is at apogee (251,876 miles from Earth), 11:48 a.m. EDT

4 Earth is at aphelion (94.5 million miles from the Sun), 1 a.m. EDT

The Moon passes 0.2° north of Antares, 10 p.m. EDT

5 Neptune is at opposition

7 Full Moon is at 9:23 p.m. EDT

8 The Moon passes 1.5° south of Saturn, 10 a.m. EDT

14 Saturn is at opposition

15 Jupiter is in conjunction with the Sun

Last Quarter Moon is at 7:04 a.m. EDT

19 The Moon is at perigee (226,485 miles from Earth), 7:18 a.m. EDT

The Moon passes 4° north of Venus, 11 p.m. EDT

21 New Moon is at 10:54 p.m. EDT; total solar eclipse

28 Delta Aquarid meteor shower is at its peak

29 Mercury passes 0.04° north of Regulus, 2 a.m. EDT

First Quarter Moon is at 10:01 a.m. EDT

31 The Moon is at apogee (251,332 miles from Earth), 4:20 a.m. EDT

Eye on the Sky by Deborah Byrd

A SUNSET ECLIPSE FOR THE NORTHWEST

Observers in the northwestern United States, western Canada, Alaska, and Hawaii can witness a partial eclipse of the Sun late in the day on July 21. The eclipse reaches its maximum phase at, or just before, sunset except in Alaska where it occurs in late afternoon. (For example, in Vancouver the Sun is only 3° high at maximum eclipse, 2° high in Seattle, and 1° high in Portland, Oregon.) See the chart below for details on how much of the Sun is eclipsed from your location.

Although most of northwest North America experiences a partial solar eclipse, a total eclipse may be visible from Atka, Amlia, Seguam, and Amukta in the Aleutian Islands. Unfortunately, the weather in the Aleutians at this time of year is dismal — there is only a 1-percent chance of clear weather on eclipse day. Totality is also visible from Finland and the northern Soviet Union. (See Through the Eyepiece on page 57 for details on viewing the eclipse from Europe and Asia.)

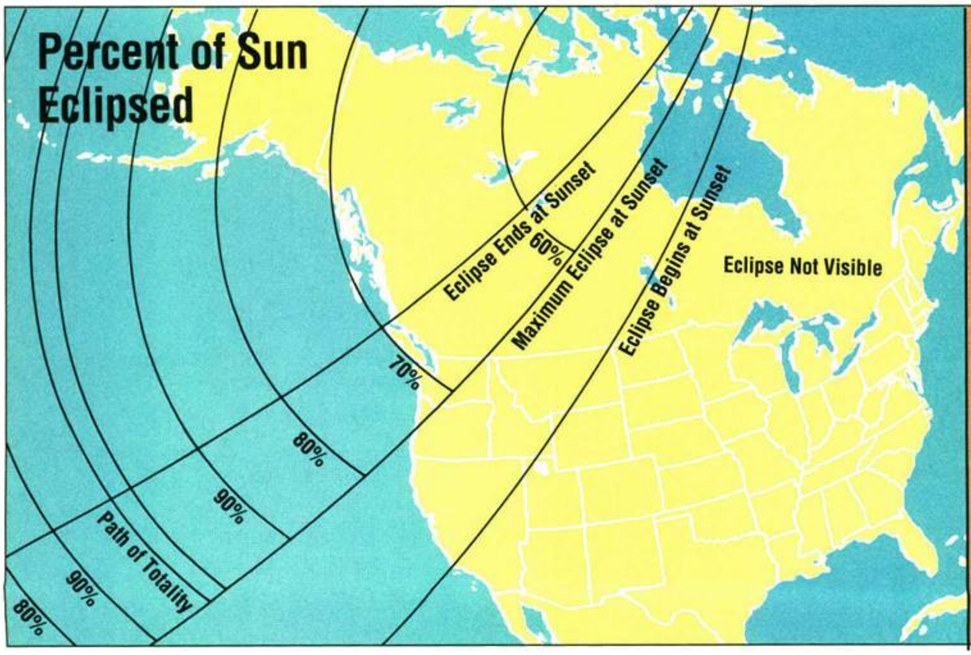
When viewing this or any solar eclipse, remember that you *must* protect your eyes. The photosphere of the Sun is always blinding, even when it is partly covered by the Moon. One way to view the eclipse safely is to make a pinhole in a piece of cardboard and project the Sun's image through the hole onto white paper. Or you can safely gaze toward the Sun through Number 14 or darker welder's glass. Check your yellow pages under "Welding Supplies."

SATURN IS BRIGHT ALL NIGHT

This is Saturn's month as the distant world peaks in brightness and is visible throughout the night. Both of these events occur when Earth passes between the Sun and Saturn and Saturn appears opposite the Sun in our sky. This opposition occurs on July 14. On that day the planet rises in the east-southeast at sunset and sets in the west-southwest at dawn. Saturn is also closest to Earth at opposition, which is why it shines so brightly. At magnitude 0.1 it appears brighter than all the summer stars except Arcturus and Vega.

Usually when Earth passes between the Sun and an outer planet, we pass slightly above or below an imaginary line between that planet and the Sun. That's not the case at this opposition of Saturn, however. Saturnian observers (equipped with telescopes and suitable protective

A PARTIALLY ECLIPSED SUN illuminates the horizon in this 1974 photo by Ernest Piini. A similar view will greet observers in the northwestern United States and western Canada before sunset on July 21. Map by Fred Espenak, NASA/Goddard Space Flight Center.

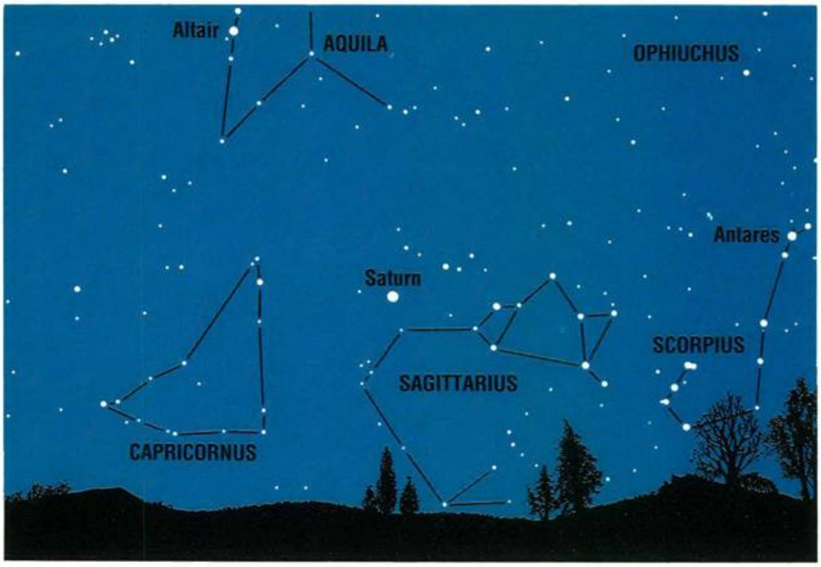


Time and Percent of Maximum Eclipse

City	Local Time	Percent Eclipsed
Anchorage	7:24 p.m.	76
Atka	7:35 p.m.	100
Barrow	7:05 p.m.	77
Billings	8:56 p.m.	13
Boise	9:19 p.m.	45
Calgary	9:32 p.m.	64
Edmonton	9:28 p.m.	63
Fairbanks	7:17 p.m.	74
Honolulu	6:29 p.m.	69
Juneau	7:28 p.m.	69
Nome	7:15 p.m.	85
Portland	8:44 p.m.	72
San Francisco	8:28 p.m.	45
Seattle	8:40 p.m.	70
Vancouver	8:38 p.m.	69
Victoria	8:40 p.m.	70

filters) would see a "transit" of Earth as our planet, a black dot, crosses the Sun's face.

Twelve hours after Saturn reaches opposition the planet Jupiter passes directly behind the Sun as seen from Earth, the only planet to do so during 1990. Thus, for this half day, Jupiter, the Sun, Earth, and Saturn are all aligned in space.



SATURN SHINES BRIGHTLY in the southeast during the late evening hours of July. The ringed planet reaches opposition, when it rises at sunset and sets at sunrise, on July 14.

A PLETHORA OF METEORS

People who live or camp under dark rural skies know that late summer is often the best time of year to watch for meteors, or "shooting stars." The weather is warm, the night sky beckons, and two major meteor showers take place.

The Delta Aquarid shower rambles along from mid-July through the end of August. Although this shower produces more total meteors than any other during the year, the Delta Aquarids are not widely known because they never reach a sharp peak of activity. The famous Perseid meteor shower, on the other hand, begins in late July and reaches a definite peak on August 12.

The best time to observe meteors this summer is in the last week of July. The Moon reaches First Quarter phase on July 29, less than a full day after the shallow peak of the Delta Aquarids, so it is absent from the prime observing hours after midnight during this period. By early August the Moon is waxing toward Full and remains bright in the morning sky through the peak of the Perseids.

JULY'S PLANETS

Golden-hued Saturn is the least flashy of the bright planets but this month it shines at its brightest for 1990 at magnitude 0.1. The planet is brightest now because it reaches opposition on July 14 and is therefore closest to Earth for the year.

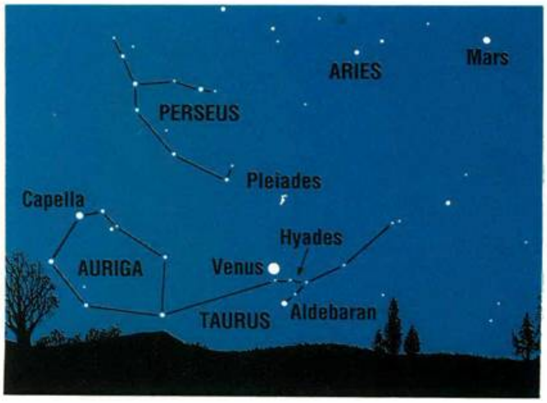
Saturn is 0.1 magnitude fainter this year than it was at last year's opposition. This may seem paradoxical because Saturn is now moving toward perihelion (its closest point to the Sun in its orbit) and is 2.5 million miles closer to us now than it was last year. The reason it is both fainter and closer is apparent through a small telescope: The rings of Saturn are now less open with respect to Earth than they were last year. Saturn's rings contribute greatly to the planet's overall brightness. As they appear less open, the planet's brightness declines.

Mars rises shortly after midnight and is well up in the southeast by dawn. In early July the Red Planet shines at magnitude 0.3 against the background stars of Pisces. By month's end Mars brightens to magnitude 0.0 and crosses into Aries.

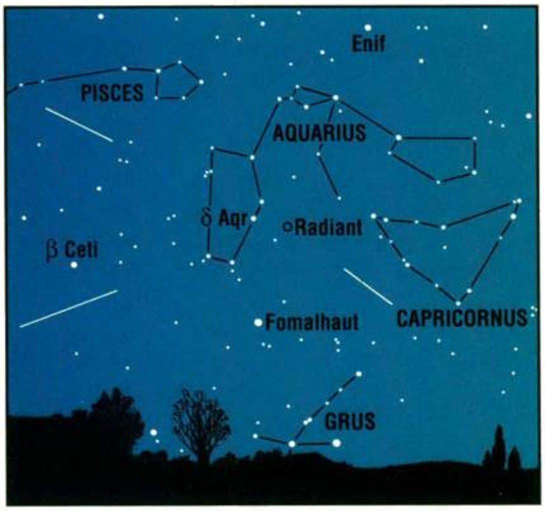
Mars is getting brighter because we are moving closer to it. Between now and November we will continue to creep up on the planet and it will grow brighter and rise earlier each day.

Venus, the brightest of all the planets, shines low in the east-northeast before dawn. At the beginning of July Venus lies between two prominent star clusters, both of which are in the constellation Taurus. The tiny dipper-shaped Pleiades cluster is above Venus and the V-shaped Hyades cluster is below.

Venus also lies less than 5° from the brightest star in Taurus,



VENUS LIES BETWEEN the Pleiades and Hyades in early July. Look for the brilliant planet low in the east-northeast around the start of morning twilight.



SEVERAL METEOR SHOWERS grace the morning sky in late July, but the best is the Delta Aquarid shower. Expect to see ten to thirty meteors per hour after midnight emanating from the constellation Aquarius.

called Aldebaran, as the month opens. Aldebaran, a nearby star superimposed on the more distant Hyades cluster, represents the fiery eye of Taurus the Bull.

Jupiter is in superior conjunction, when it passes directly behind the Sun, on July 15. You'll have to search hard to see it at all this month, but you may spot it low in the east-northeast about 10° below and to the left of Venus at month's end.

Innermost Mercury is also on the far side of the Sun in early July, in superior conjunction on July 2. It becomes visible in the west after sunset by the end of the month, but you'll have to look carefully and maybe sweep with binoculars to see it. Mercury passes within a degree of the 1st-magnitude star Regulus on the evening of July 28, when Mercury is the brighter object at magnitude –0.1.

JULY'S STARRY SKY

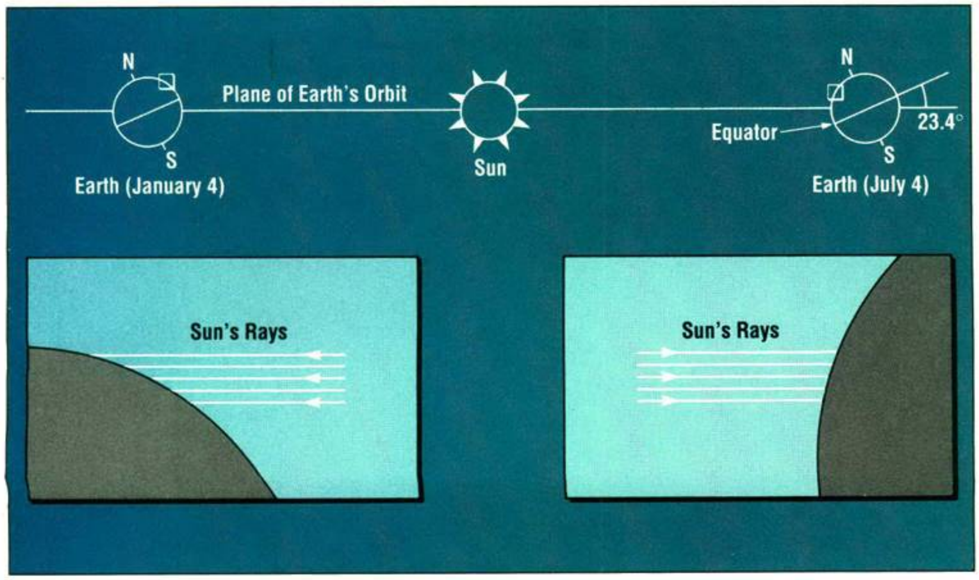
This month we focus on a daytime star, our own Sun. Every July Earth reaches aphelion, its farthest point from the Sun in its orbit. Aphelion takes place this year around midnight on July 3/4. At that time we are approximately 94.5 million miles from the Sun, in contrast to our closest distance of 91.4 million miles in early January.

If Earth wasn't tilted on its axis this change in distance from the Sun would be more meaningful. It would create seasons, with winter occurring across the globe in July and summer in January. The change would not be dramatic, however, because our orbit around the Sun is nearly circular.

However, as we all learned as schoolchildren, Earth's axis is tilted with respect to its orbit around the Sun. This 23.4° tilt is what creates the rhythmical, seasonal changes in the quality of the light and the temperature of the air at any given location on our world. As we orbit the Sun the Northern and Southern Hemispheres take turns leaning toward our star. The hemisphere that receives the Sun's rays most directly has summer while the other hemisphere has winter.

And yet the notion persists that a planet's distance from the Sun should have some effect. And indeed it does, *if* that planet's orbit is markedly noncircular. The planet Mars is a good example. Its orbit is much more elliptical than Earth's, and thus its distance from the Sun changes more significantly in the course of each Martian year. (At its closest, Mars is 128 million miles from the Sun; at its most distant it is 155 million miles away.) Mars tilts on its axis about 25°, nearly the same amount as Earth, and these two effects combine to create major seasonal differences between the planet's two hemispheres. The northern hemisphere of Mars undergoes only mild seasonal changes, while the southern hemisphere endures severe ones. That's because Mars is always closest to the Sun when it is winter in the north and summer in the south. Likewise, Mars is farthest from the Sun during the northern summer and southern winter. ☐

EARTH IS FARTHER from the Sun in July than in January (top), but the Northern Hemisphere is nevertheless warmer in July. That's because the Northern Hemisphere is now tilted toward the Sun and the Sun's rays beat down more directly (below, shown for 40° north latitude).

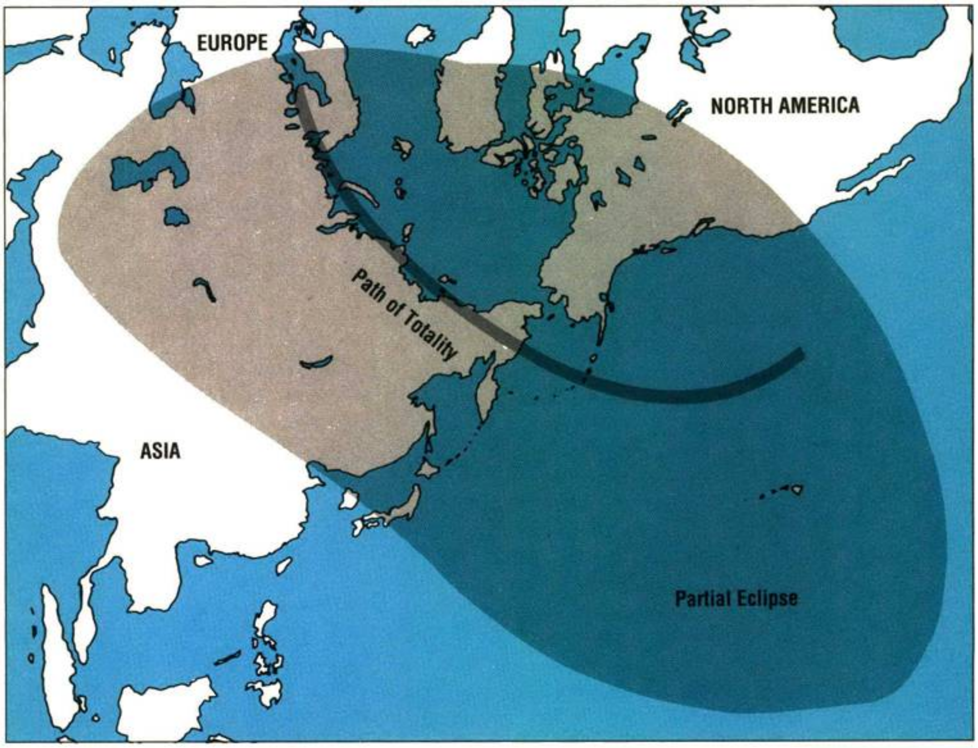


Deborah Byrd is the creator, writer, and producer of "Star Date," a syndicated radio series on commercial and public radio.

TOTAL ECLIPSE IN NORTHERN EUROPE AND ASIA

On July 22 observers in parts of Finland and the northern Soviet Union have a chance to view that most exquisite of celestial events — a total solar eclipse. The path of totality first touches Earth near Helsinki, Finland, at sunrise and then travels northeast into the Soviet Union. The eclipse track skirts the long Arctic coast of that country until reaching eastern Siberia, where the eclipsed Sun attains its highest altitude (40°) and totality lasts longest (two minutes and thirty-six seconds).

The path of totality then leaves the Asian mainland, crosses the International Dateline (where it becomes the afternoon of July 21), sweeps across the Aleutian Islands, and ends at sunset in the Pacific about halfway between Honolulu and San Francisco. Observers in much of Scandinavia, northern Europe and Asia, western Canada, and the northwestern United States can see a partial solar eclipse.



A TOTAL SOLAR ECLIPSE darkens the sky over extreme northern Europe and Asia on July 22. Much of the rest of Eurasia experiences a partial solar eclipse.

Because the Sun is now near sunspot maximum, this eclipse offers an excellent opportunity to see or photograph the Moon as it gobbles up a sunspot or two. However, no celestial event is worth damaging your eyesight over, so follow these rules. 1) The *only* time it is safe to view a solar eclipse without protection is when the Moon entirely covers the Sun's surface. 2) The only safe ways to view the Sun through a telescope are by using solar projection or a good over-the-aperture filter securely attached to your telescope. 3) Make sure you either cover or attach a filter to your finder scope.

SATURN AND ITS SATELLITES

Saturn reaches opposition on July 14, so the ringed planet is well-placed for observing this month. At the beginning of the month Saturn rises during evening twilight and transits about 2 a.m. local daylight time. By the end of July Saturn is well up in the southeast at sunset and transits before midnight.

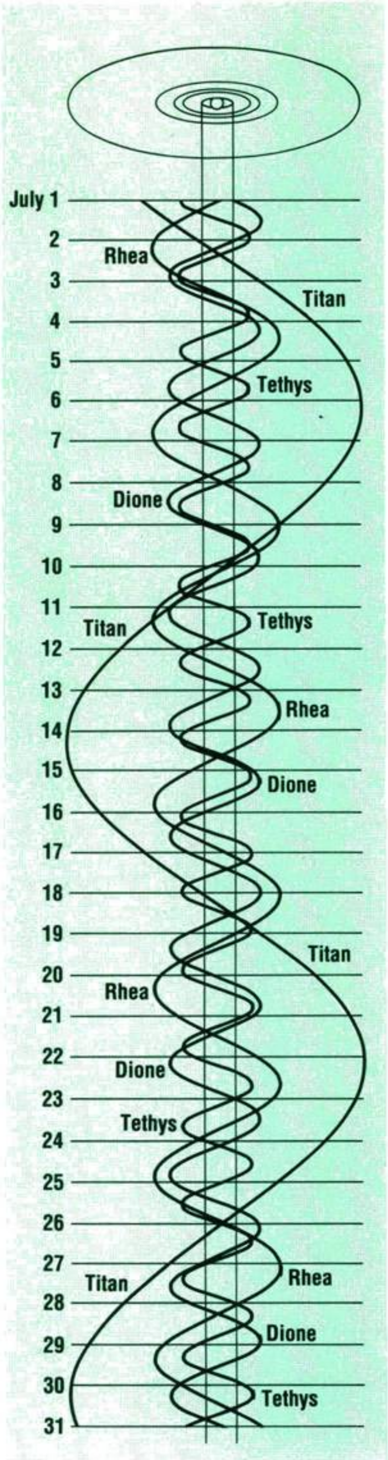
At opposition Saturn shines at magnitude 0.1 and measures 18.4" across its disk and 41.9" across the rings. Saturn appears slightly larger now than it has since 1986 because it is slowly moving closer to the Sun in its orbit. That makes observing ring features like Cassini's division relatively easy this month.

Unlike Jupiter, where there is a wealth of atmospheric activity to observe, Saturn normally presents a relatively bland surface. Although the planet has a banded atmosphere much like that of Jupiter, the brightness contrast between regions is much lower. About the only features you can generally make out are a dusky equatorial band and the darker polar regions.

The most dynamic aspect of the Saturnian system is the planet's moons. Saturn's satellites don't often put on the same kind of show as Jupiter's Galilean satellites do, however. Most of Saturn's bright satel-

Time and Percent of Maximum Eclipse

City	Universal Time	Percent Eclipsed
Archangel'sk	1:53	98
Beijing	2:10	1
Gorki	1:42	82
Helsinki	1:53	100
Irkutsk	1:56	40
Joensuu	1:54	100
Kabul	1:14	10
Leningrad	1:51	97
Moscow	1:43	85
Novosibirsk	1:42	55
Oslo	2:35	31
Sapporo	3:04	30
Stockholm	2:10	72
Tallinn	1:52	100
Tampere	1:55	99
Tashkent	1:21	28
Tokyo	3:13	8
Turko	1:55	99
Ulan Bator	1:56	26
Vladivostok	2:44	21



FOLLOW SATURN'S SATELLITES as they revolve around the ringed planet this month. The horizontal lines give the moons' positions at 10 p.m. PDT (11 p.m. MDT, midnight CDT, and 1 a.m. EDT), but you can use the diagram to find where the moons will be throughout July. (See text for further details.)

lites lie in the same plane (the plane of the planet's rings), as do Jupiter's, but that plane is inclined 27° to the plane of the ecliptic. Depending on where Saturn is in its orbit, at some times we see the orbital plane of the rings and satellites "edge on" and at other times it appears considerably tilted. This month our line of sight touches Saturn 23° north of the ring plane. Thus, we get a glorious, wide-open view of Saturn's rings but are deprived of seeing either a satellite transit Saturn's disk or an occultation of a satellite by the planet.

Looking through a 6-inch or larger telescope you can easily spot Saturn's five brightest moons: Tethys, Dione, Rhea, Titan, and Iapetus. The easiest way to do this is by using the diagram at left. (The diagram is oriented so that south is at top to match the view in Newtonian telescopes.) The horizontal lines in the lower part of the diagram represent the satellites' positions at 10 p.m. PDT on the date shown (11 p.m. MDT, midnight CDT, and 1 a.m. EDT the next day). If you plan to observe at that hour, use the line provided for the appropriate date. If you'll be observing earlier or later, draw a horizontal line a proportional amount above or below the given line.

For example, if you plan to observe at 10 p.m. EDT on July 15, that is three hours earlier than the time for the July 15 line. Three hours is one-eighth of twenty-four hours, so draw your line one-eighth of the way from the July 15 line to the July 14 line. Once you've drawn the line for your observing time, mark the four points where the line intersects the curved lines that represent the satellites' positions. Then draw a perpendicular line from each of those points to the corresponding orbit on the Saturn diagram at the top of the page. If the satellite is moving from west to east (left to right) on the lower diagram, it lies north of (below) Saturn. If the satellite is moving from east to west (right to left), it lies south of (above) Saturn.

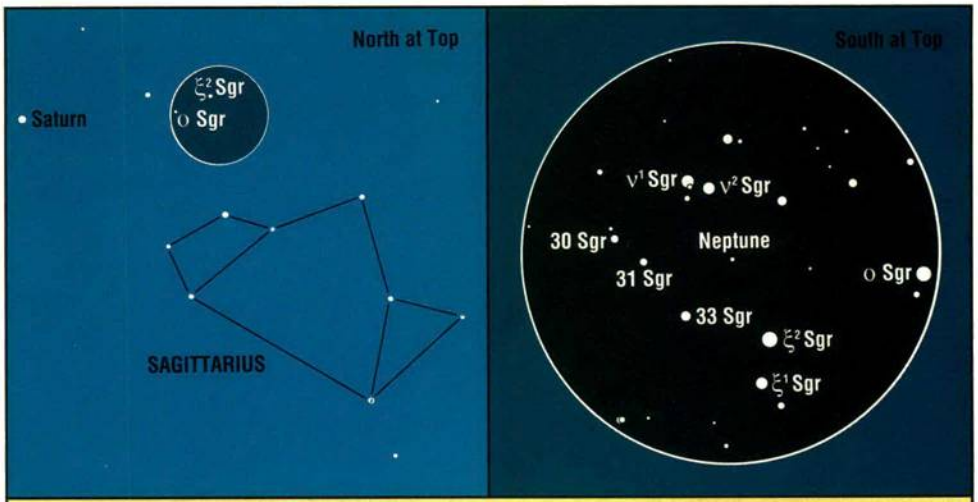
The diagram helps you find only four of the five bright moons. The fifth, Iapetus, circles Saturn in an orbit so large that it won't fit on the diagram. Iapetus starts July just east of due north of Saturn and about 100" from the planet's center, or about two and a half times the apparent diameter of the rings. By the night of July 17/18 Iapetus is at greatest eastern elongation and lies a whopping 530" east of Saturn.

Iapetus is one of the strangest moons in the solar system, with one hemisphere reflecting 5.2 times as much sunlight as the other. Because Iapetus rotates once every 79.33 days (the same period it takes to revolve around Saturn) the moon presents a different face to us at eastern elongation than it does at western elongation. At eastern elongation on July 17/18 the dark hemisphere faces Earth and the satellite shines at magnitude 11.9. At western elongation on August 26, we see the bright hemisphere and the satellite shines at magnitude 10.1.

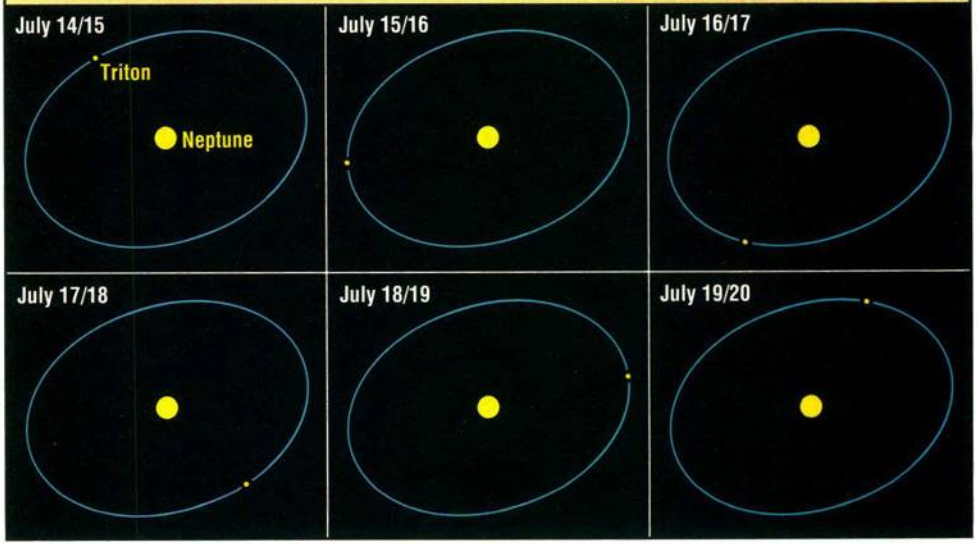
Aside from Iapetus, Titan is the only other Saturnian satellite with characteristics that can be observed in many backyard telescopes. Titan appears noticeably orange-red due to its rather dense atmosphere of nitrogen and trace amounts of assorted hydrocarbons. Titan is also large enough to present a discernible disk (0.8" across) in 8-inch or larger telescopes under excellent seeing conditions.

TELESCOPIC PLANETS

Mercury begins a rather unfavorable evening apparition for Northern Hemisphere observers in late July when it appears low in the west after sunset. The premier event in Mercury's month occurs on the evening of July 28 when the inner planet passes just 0.04° north of the 1st-magnitude star Regulus. Although closest approach occurs after Mercury sets in North America, the two lie within 0.3° of each other thirty minutes after sunset and are easily visible in the same telescopic field. Regulus appears as a bright pinpoint of light and Mercury displays a 6.2"-diameter, 69-percent-lit disk that shines at magnitude –0.1.



FINDING NEPTUNE'S MOON TRITON is a challenge, but you can glimpse it if you know where to look. First, find Sagittarius and the stars ο Sgr and ξ² Sgr with the naked-eye star chart (above left), then locate Neptune with the wide-field telescopic finder chart (above right). The diagrams below show a telescopic view, with south at top, of Triton's position relative to Neptune at 10 p.m. PDT (11 p.m. MDT, midnight CDT, and 1 a.m. EDT) on six days in mid-July.



Venus is much easier to see in the morning sky than Mercury is in the evening sky. The bright planet shines at magnitude –3.9 and rises two hours before the Sun. Telescopically, however, Venus has little to offer. The 11.7"-diameter disk is 87-percent lit on the 15th and changes little throughout July.

Although it is much fainter than Venus, Mars is a more rewarding telescopic object this month. The Red Planet rises five hours before the Sun and exhibits a ruddy disk that measures 8.4" across at midmonth. Now is the time to start tuning up for Mars' November opposition. If you begin observing the planet now you can train your eye to discern the wealth of subtle detail Mars will offer later this year.

Jupiter is almost perfectly out of phase with Saturn this month, reaching conjunction with the Sun half a day after Saturn is at opposition. You might be lucky enough to catch a glimpse of the giant planet at the end of July, but the –1.8-magnitude planet is so close to the horizon that you won't get a satisfying view.

The same is not true of Uranus and Neptune, however. Both of these gas giants are well-placed for viewing in Sagittarius. Uranus shows a 3.8"-diameter, blue-green disk that shines at magnitude 5.6 in July. Neptune, which reaches opposition on July 5, is a 7.9-magnitude, blue-gray world that appears 2.3" in diameter.

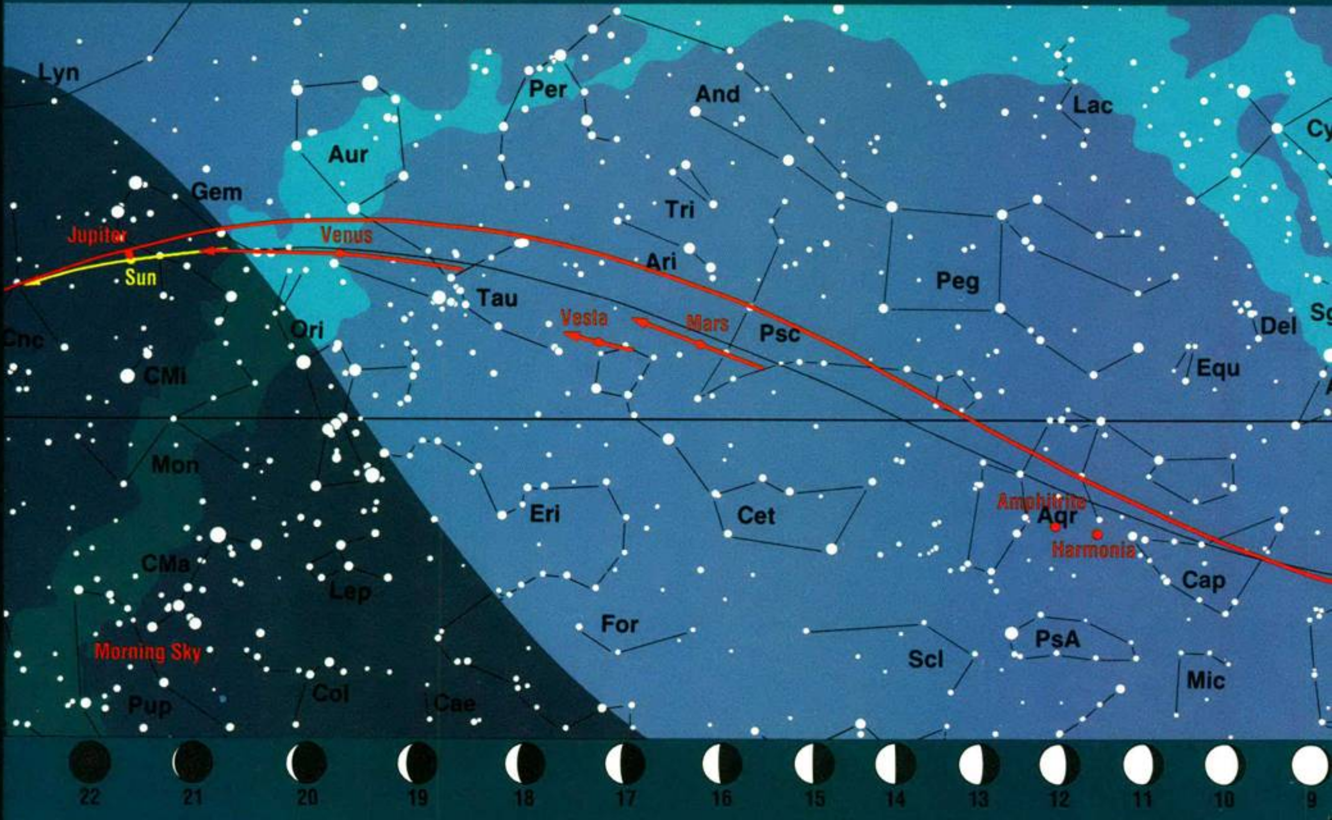
If you own an 8-inch or larger telescope you can also try to observe Triton, Neptune's lone large satellite. Revealed in detail for the first time by *Voyager 2* a year ago, Triton appears as a 13.5-magnitude dot at a maximum distance of 17" from Neptune. Use the diagrams above to locate Triton when the Moon is out of the sky at midmonth.

ASTEROIDS IN THE EYEPIECE

Asteroid 8 Flora reached opposition on June 29 and remains a 9th-magnitude object in Sagittarius throughout July. You can locate Flora using the chart or table of coordinates in last month's Through the Eyepiece. Pay particular attention to this minor planet on July 27 and 28. On those nights Flora passes in front of the open cluster M21 and occults several cluster members (although the occultations themselves are not visible from North America). □

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He is also a telescope and Frisbee nut, owning more than a few of both.

The Solar System July 1990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Eri
Cet
Amphitrite
Aqr
Harmonia
CMa
Cap
Lep
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PsA
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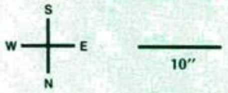
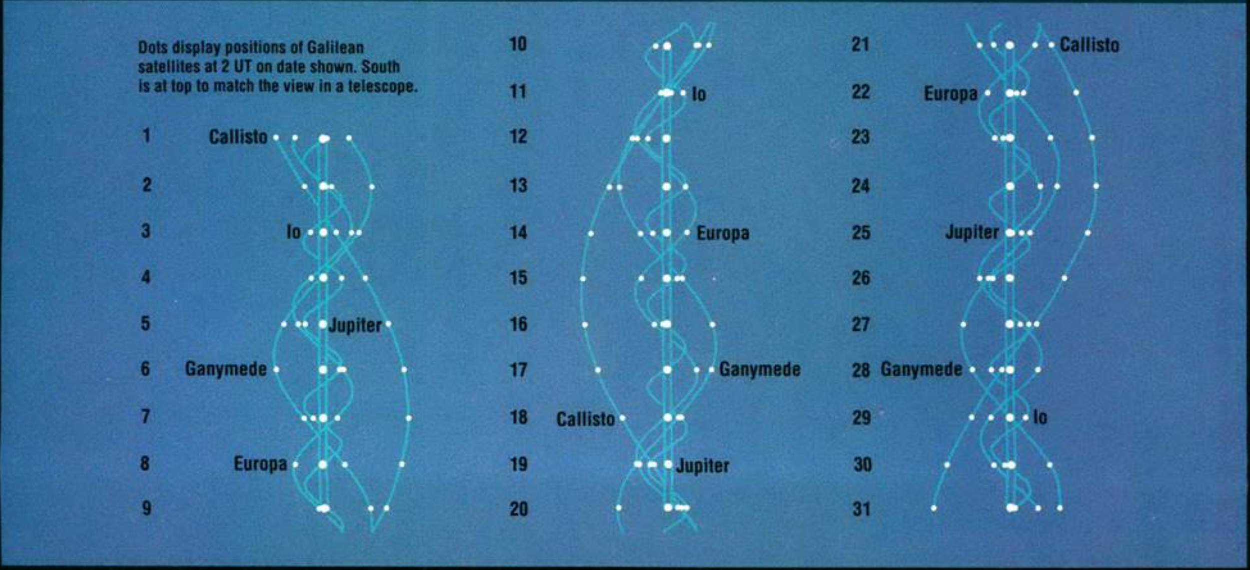
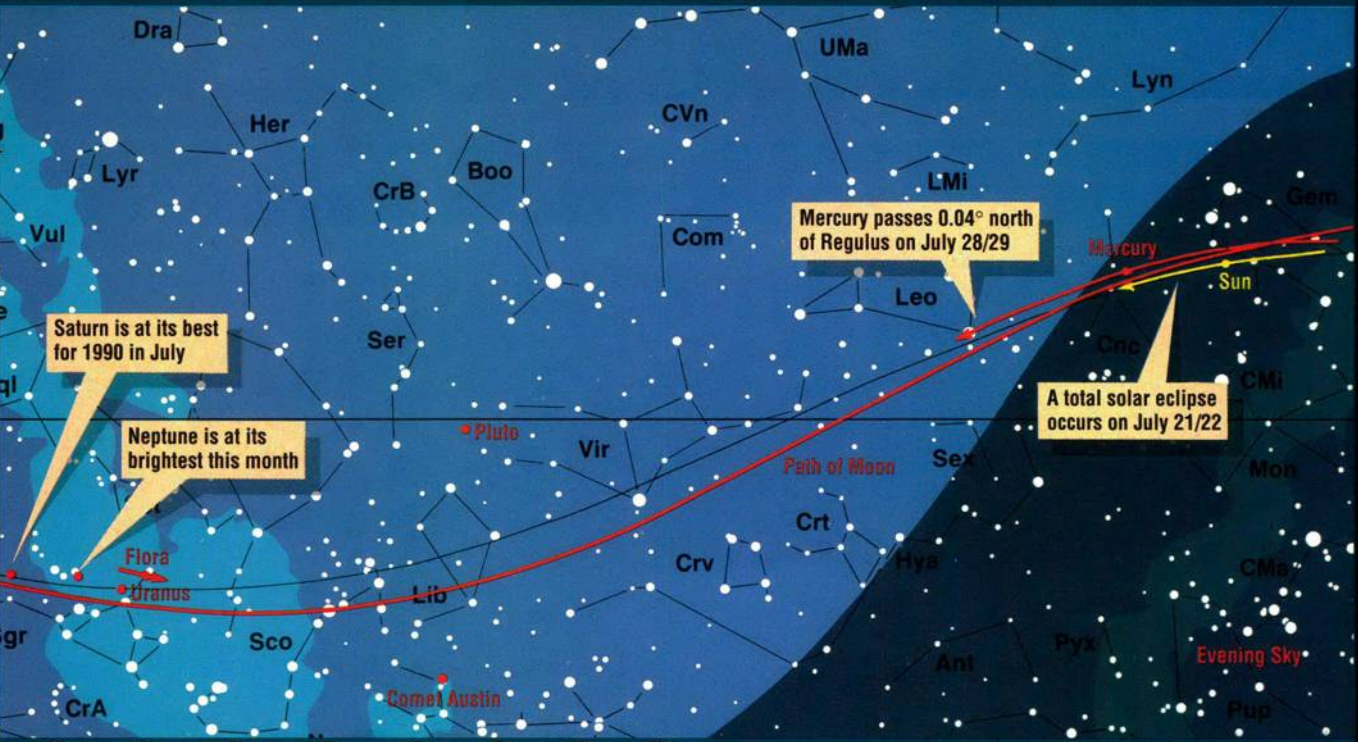


Planet	MERCURY	MERCURY	VENUS	MARS
Date	July 15	July 31	July 15	July 15
Magnitude	–0.8	0.0	–3.9	+0.2
Angular Size	5.3″	6.3″	11.7″	8.4″
Illumination	88%	66%	87%	84%
Distance (AU) from Earth	1.268	1.067	1.431	1.117
Distance (AU) from Sun	0.369	0.447	0.723	1.383
Right Ascension (2000.0)	8h35.2m	10h17.5m	5h33.8m	2h01.2m
Declination (2000.0)	20°31′	10°53′	22°19′	10°08′

Jupiter's Moons


Dots display positions of Galilean satellites at 2 UT on date shown. South is at top to match the view in a telescope.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Mercury
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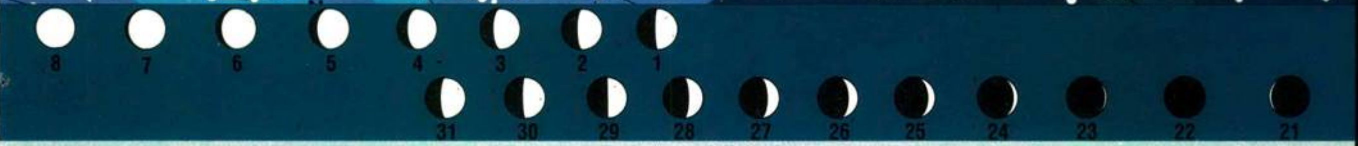
CMi
Pluto
Vir
Path of Moon
Sex
Mon
Crt
Flora
Uranus
Crv
Hya
CMa
Lib
gr
Sco
Ant
Pyx
Evening Sky
CrA
Comet Austin
Pup

Mercury passes 0.04° north of Regulus on July 28/29

Saturn is at its best for 1990 in July

Neptune is at its brightest this month

A total solar eclipse occurs on July 21/22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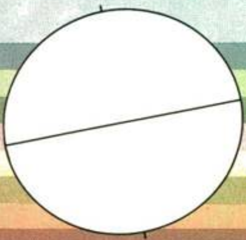
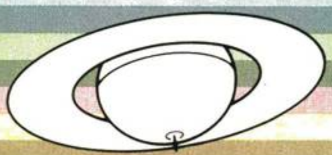
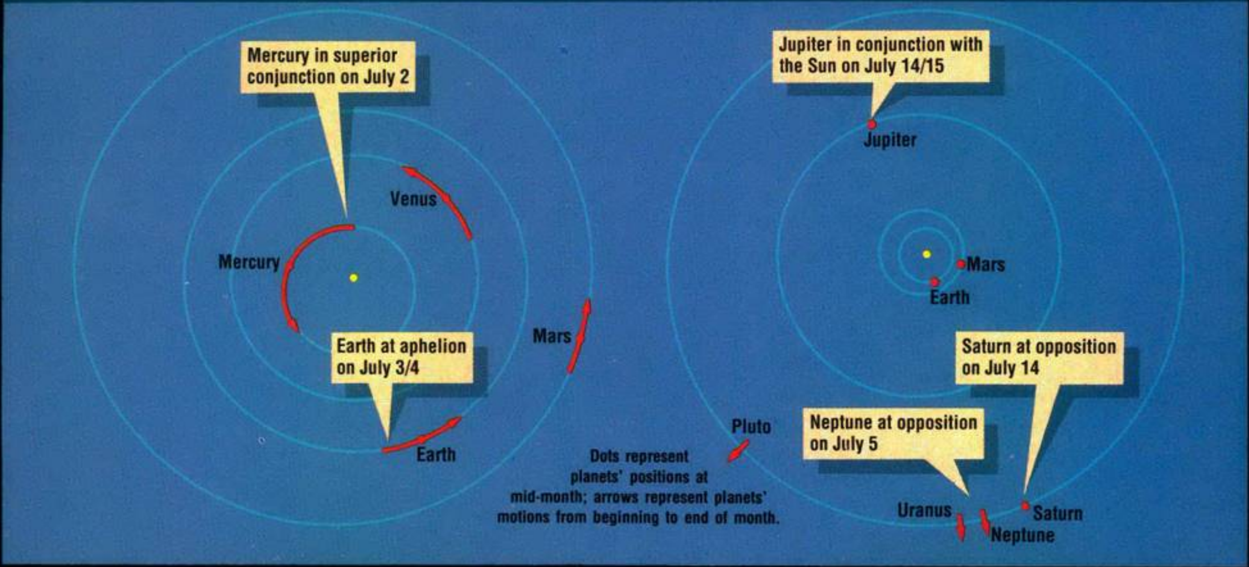




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
−1.8	+0.1	+5.6	+7.9	+13.7
31.6"	18.4"	3.8"	2.3"	0.1"
100%	100%	100%	100%	100%
6.238	8.994	18.433	29.203	29.267
5.222	10.010	19.415	30.206	29.660
7h37.7m	19h35.5m	18h31.0m	18h56.4m	15h08.7m
21°47'	−21°33'	−23°35'	−21°56'	−1°24'

The Planets in Their Orbits


Venus
Mercury
Mars
Earth
Jupiter
Mars
Earth
Pluto
Uranus
Saturn
Neptune

Mercury in superior conjunction on July 2

Earth at aphelion on July 3/4

Jupiter in conjunction with the Sun on July 14/15

Saturn at opposition on July 14

Neptune at opposition on July 5

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

How to Take a Planetary Portrait

Using some simple techniques you can capture the rings of Saturn and the clouds of Jupiter on film.

by Mark J. Coco

If you own a telescope, you've no doubt spent many hours observing the planets. But have you ever wished you could photograph them? Capturing the rings of Saturn and the cloud belts of Jupiter on film has always been one of the prime reasons people get into astrophotography, and rightly so. Compared to other types of astrophotography, taking pictures of the planets is relatively easy. Planets are bright. By astrophotography standards the exposures they require are short, only a few seconds at most. These are literally a snap compared to the tedious minutes and hours of patient guiding required for most deep-sky photographs.

The short exposures also mean there is no need to worry about light pollution washing out your subject. You don't have to drive tens of miles seeking dark skies. In fact, you can photograph the planets right from downtown if you want.

But while taking planetary portraits may be easy, taking good planet shots takes care, skill, and the right equipment.

Planetary Portrait Equipment

When you try to photograph the planets, the first thing you discover is that the telescope and camera combination alone can't provide enough magnification to record an image of a reasonable size. For example, an image of Jupiter at the prime focus of a telescope with a 2000mm focal length (an 8-inch Schmidt-Cassegrain, for example) is a mere 0.4 millimeters across. Even with a fine-grain film this is much too small to show any detail. A planet image should be at least 2 to 4 millimeters across.

You can get a larger planetary image by using an eyepiece to project a magnified image of the subject onto the film. This technique, called eyepiece projection, is similar to the way a slide projector takes the small image of a 35mm slide and casts an enlarged image onto a screen. In this case the screen is a piece of film and the projector lens is the eyepiece.

Eyepiece projection is used on any object requiring more magnification than the telescope alone provides. It is used for planets and for close-up shots of sunspots, lunar craters, and even double stars. By using an eyepiece to boost the power it is possible to achieve effective focal lengths of up to 40,000mm. At that enormous magnification, Jupiter is 8.0 millimeters across on the film frame, which is large enough to record detail on the disk.

THE FAVORITE TARGET of planetary photographers is captured in this 13-second exposure with a 16-inch telescope. Photo by Mark Coco and Scott Roberts.

To attain the high power of eyepiece projection photography, a 3-inch telescope is an absolute minimum. A 5- to 6-inch telescope is far better. Although you can increase the image size of any planet simply by using a higher power eyepiece (which increases the effective focal length), a small telescope simply doesn't provide enough light to keep the exposures to a reasonable length. The right amount of magnification with a small telescope can produce images that are big enough but they'll be faint. Faint translates into long exposures, and long exposures produce blurring from turbulence, wind, and ground vibration. The larger the telescope, the more light you'll have and the shorter the exposure will be.

To keep images sharp and motionless during the few seconds of the exposure, your telescope must be on a solid equatorial mount with an accurate clock drive. You'll also need an adapter that attaches your camera (with its normal lens removed) to the telescope while the eyepiece is in place. These accessories, which can be purchased from commercial suppliers, are sometimes called tele-extenders or projection adapters. To provide a range of projection magnifications, you'll need a range of eyepieces, anything from 25mm on the low power end to 5mm on the high power end. The best type of ocular for eyepiece projection is the orthoscopic design. It offers crisp images with a very flat field. Plössls also work well, though they are susceptible to "ghost images" from internal reflections.

Depending on your telescope, you may also need some counterweights.

Calculating Your Power

To determine the right exposures, you'll first need to calculate the effective focal length and f/ratio of your eyepiece projection set-up. A simple formula will help you out:

f/ratio for eyepiece projection = telescope's f/ratio x (D–F) / F

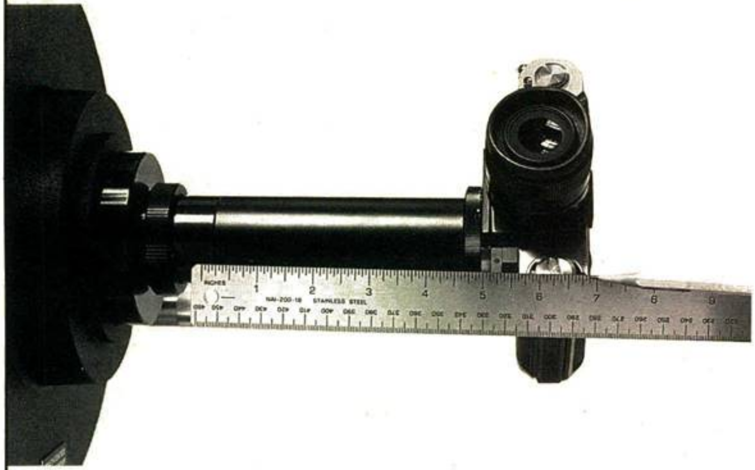
where *D* is the distance from the focal plane of the eyepiece (usually near the middle of the eyepiece) to the film plane at the back of the camera and *F* is the focal length of the eyepiece. The telescope's f/ratio is its normal f/ratio at prime focus.

Take an 8-inch (200mm aperture) f/10 Schmidt-Cassegrain telescope with a focal length of 2000mm. The standard Schmidt-Cassegrain tele-extender separates the eyepiece and film by 165mm. If we use a 10mm eyepiece, our formula gives us (165 – 10) / 10 = 15.5. This is how much extra magnification the eyepiece projection set-up is producing. Multiply this number by the f/ratio of the telescope, in this case f/10. This yields an effective f/ratio of f/155.

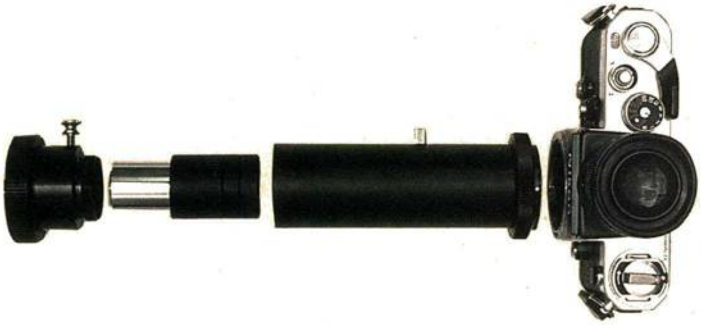
Now you're ready to compute the effective focal length (EFL). To do this multiply the new f/ratio of the telescope during eyepiece projection by the lens or mirror aperture in millimeters. The formula is:

EFL = f/ratio x objective diameter (mm)

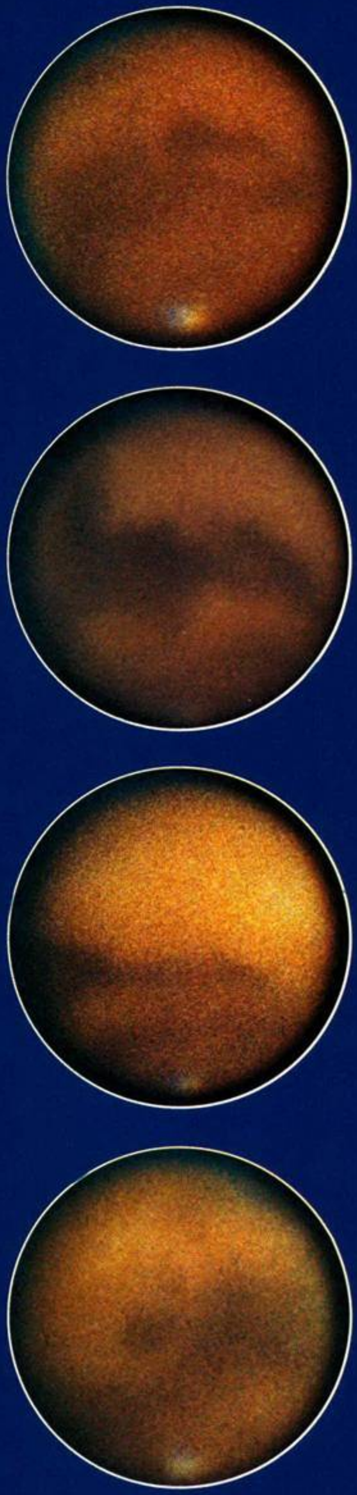
Continuing our example, take the f/ratio of 155 and multiply by the mirror diameter of 200mm. This yields an effective focal length of 31,000mm.



THE SIZE OF THE IMAGE you get depends on the focal length of the eyepiece and the projection distance from the eyepiece to the camera film plane. The longer this distance, the larger the image.

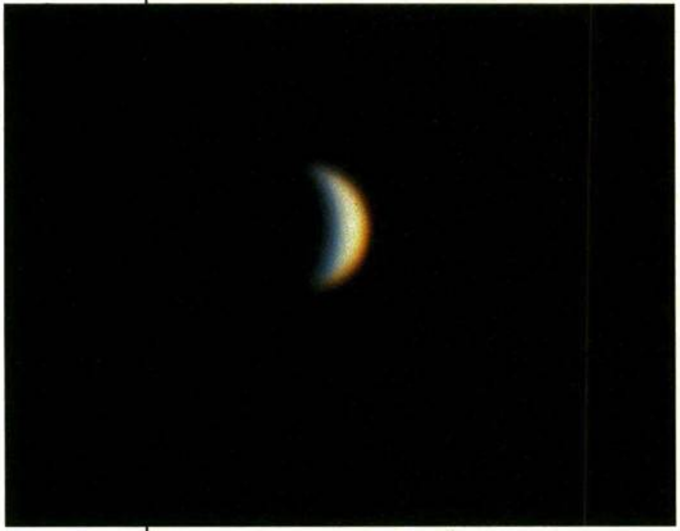


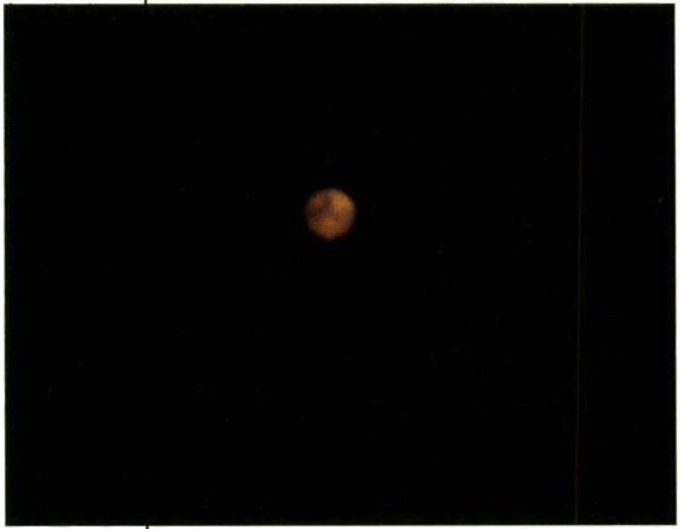
TYPICAL PROJECTION SYSTEMS consist of an adapter tube, an eyepiece, and a T-ring to attach the projection tube to your camera body.

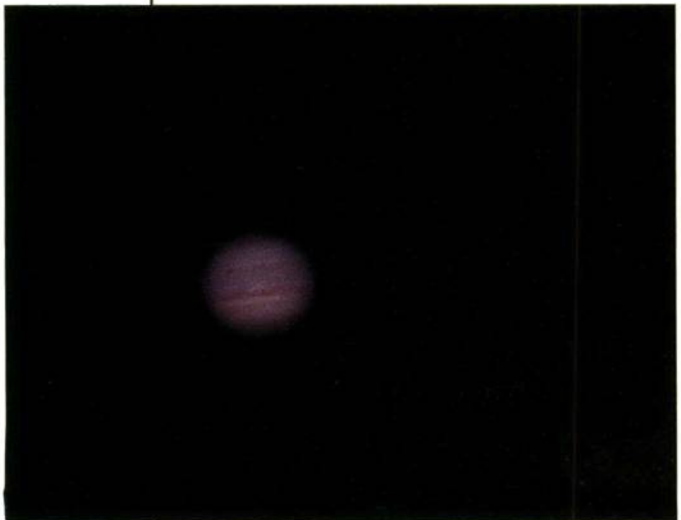


EVERY TWO YEARS Mars reaches opposition and becomes large enough to capture on film. The photos in this series were taken about a week apart in late 1988 and record a complete rotation of the planet. Photos by Harold Moore.

Planet Sizes



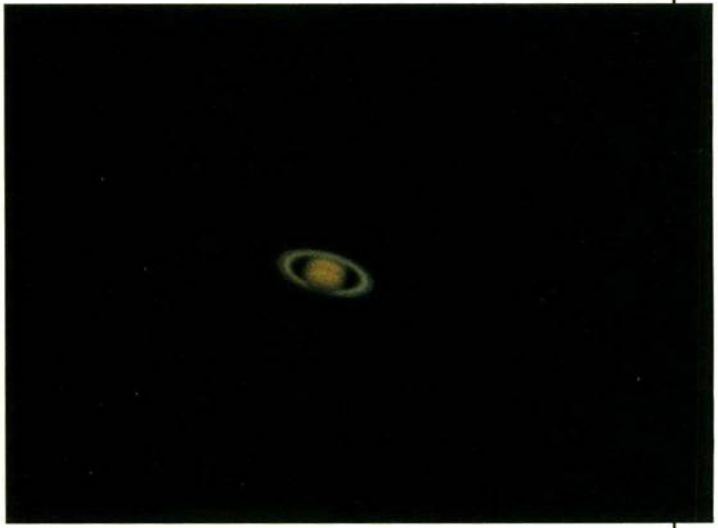




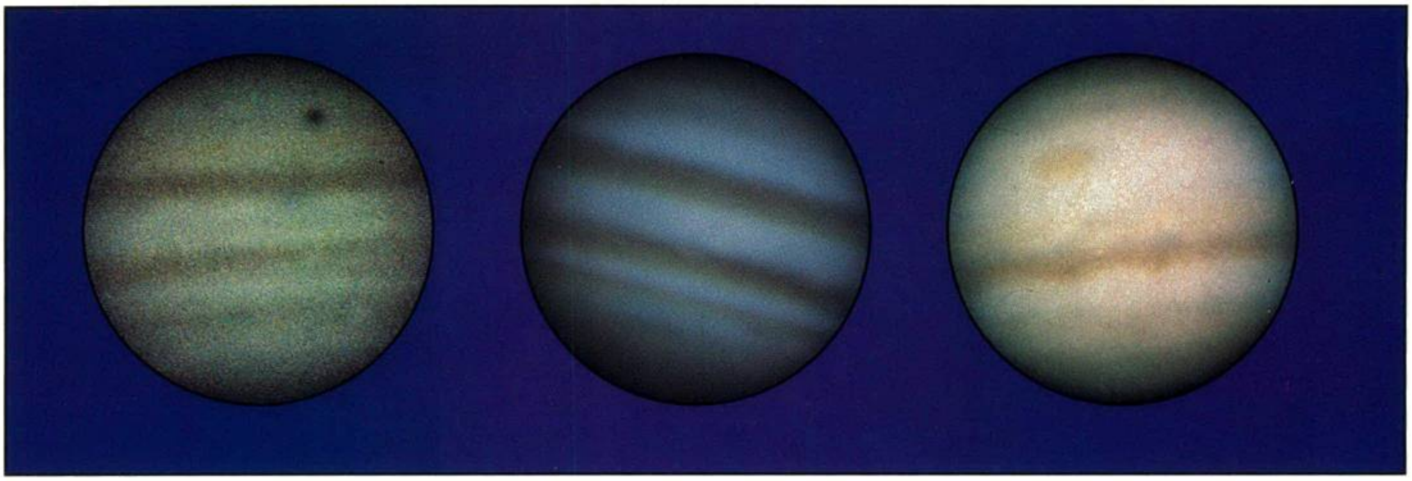
What's My Image Size?

	Actual Size (arcseconds)	Apparent Size on Film (EFL of 30,000mm)
Mercury	9	1.3 mm
Venus		
Full phase	10	1.5 mm
Quarter phase	35	5.1 mm
Crescent phase	60	8.7 mm
Mars		
Smallest size	4	0.6 mm
Average size	12	1.7 mm
Largest size	24	3.6 mm
Jupiter		
Smallest size	30	4.4 mm
Near opposition	45	6.5 mm
Saturn		
Planet diameter	16	2.3 mm
Across rings	45	6.5 mm
Uranus	4	0.6 mm
Neptune	2	0.3 mm

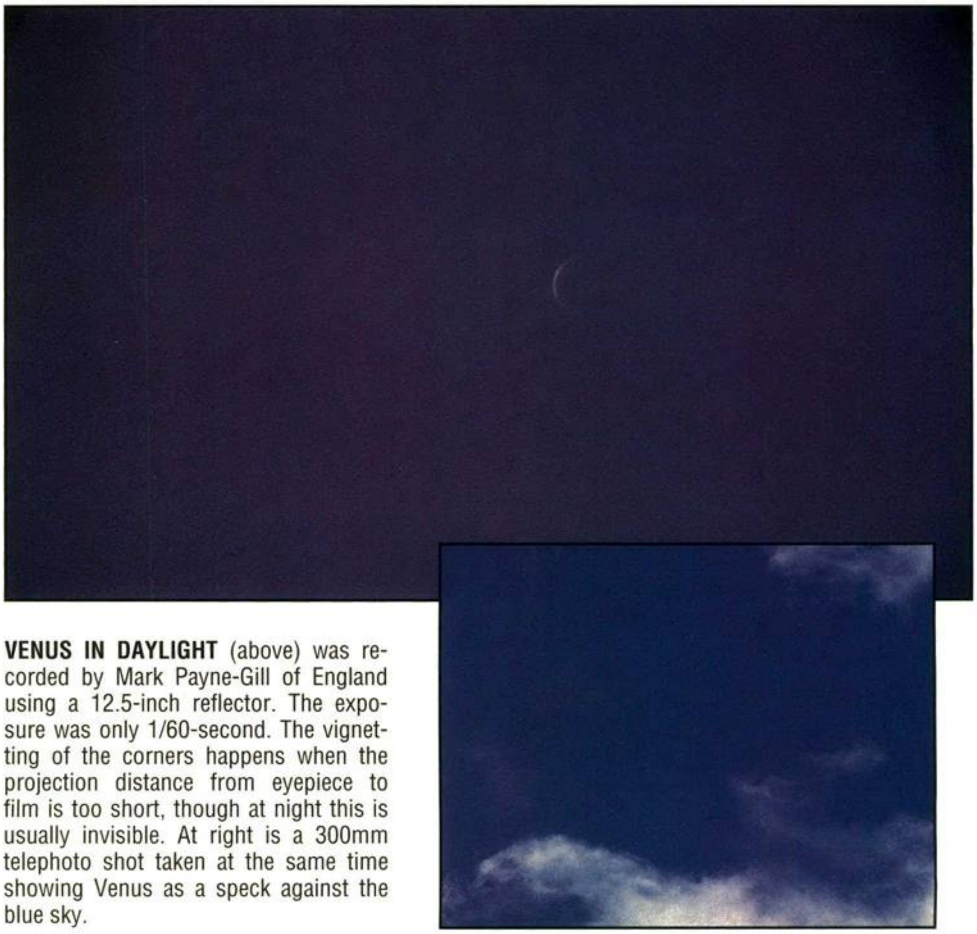
These sizes were calculated with the formula: *Size on film = (angular size in arcseconds x focal length in mm) / 206,265.*



These are the image sizes you usually work with. Each photo was taken at the same effective focal length, about 30,000mm. Each photo is reproduced full frame. Venus and Jupiter have the largest planetary disks; Saturn and Mars are always much smaller. Photos from top to bottom by Mark Coco, Bill Braithwaite, and Steve Reed. Saturn photo by David Lee.



THE CHANGING FACE OF JUPITER is a constant challenge for photographers. Jean Dragesco's 1981 photo (left) shows a transit of Ganymede and its shadow. Mark Coco's 1986 photo (middle) shows the classic twin equatorial belts. Gregory Terrance captured a dramatically different Jupiter in early 1990 (right) with a single equatorial belt and a prominent Red Spot .



VENUS IN DAYLIGHT (above) was recorded by Mark Payne-Gill of England using a 12.5-inch reflector. The exposure was only 1/60-second. The vignetting of the corners happens when the projection distance from eyepiece to film is too short, though at night this is usually invisible. At right is a 300mm telephoto shot taken at the same time showing Venus as a speck against the blue sky.

The tele-extender and camera will alter the balance of your telescope, a problem that can affect the accuracy of your clock drive. A counterweight set will rebalance the telescope. Finally, a drive corrector that allows you to fine tune the speed of your drive motor can help, but it is not essential. As long as the drive mechanism is fairly accurate and the mount is precisely polar aligned, the image shouldn't wander significantly during the exposure.

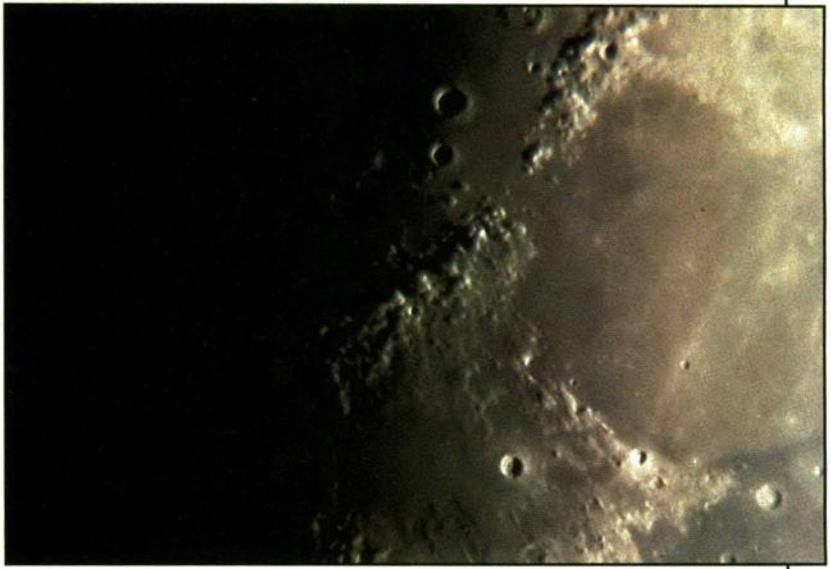
Which Film is Best?

You can go two ways when selecting the right film. The preferred route is to use medium speed films. Because of their fine grain structure they have the potential of producing the best image and revealing the finest planetary detail. For color work use Ektachrome 100HC, Ektachrome 200, or Fujichrome 100 for slides, or Ektar 125 for prints. For black-and-white images try T-Max 100 or Tech Pan 2415 (which has an ISO rating of 125 when processed in D19). Any film slower than ISO 100 is probably too slow, except when photographing Venus at its brightest. Photos of Saturn may require a film as fast as ISO 400, like Fujichrome 400.

The second and less preferable route is to use very fast films. While they offer shorter exposure times, they sacrifice image quality because of their graininess. Some astrophotographers will use fast films when the seeing conditions are marginal. This way they can get around bad seeing by using shorter exposures, hoping to catch a moment when the seeing is somewhat steady. I have used Fujichrome 1600D professional slide film with very good results. You may want to experiment with Kodak T-Max 3200 (a super-high speed black-and-white film) or Konica SR-G 3200 (a color print film). However, the best results come from combining slower, sharper films with patience for those few nights when the seeing is first rate.

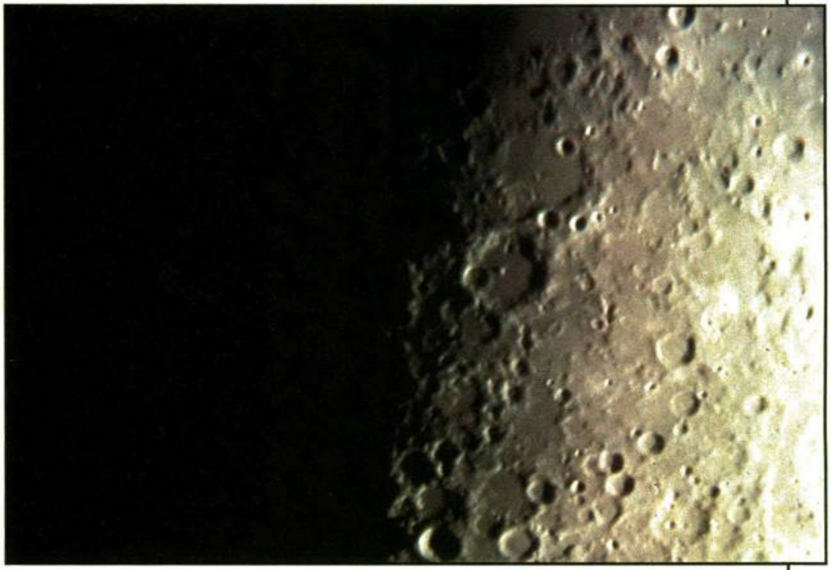
Avoiding the Fuzzies

Poor seeing conditions are the bane of the planetary photographer. Turbulence in the Earth's atmosphere, either near the ground or in the upper atmosphere, can affect the image in one of two ways. Detail can be blurred by small scale ripples or the entire image can move around the field. Either way, the result is a fuzzy image. Before starting a photo session, check the planet at high power. If either of these conditions exists, don't waste your time or your



CLOSE-UPS OF THE MOON show the power of eyepiece projection. The author used an 8-inch telescope, a 25mm eyepiece for an effective focal length of 12,400mm, and a 1/60-second exposure.

YOU COULD ENLARGE a prime focus whole-disk image of the Moon like this one for lunar close-ups, but the best results require eyepiece projection. Photo by Mark Coco.



THE CRATERED HIGHLANDS of the Moon present an interplay of shadow and light that changes by the hour. Photo by Mark Coco.

film on an exposure.

To improve your chances of encountering steady seeing conditions, the best time to photograph the planets is when they are as far above the horizon as possible. The farther above the horizon, the less atmosphere you have to look through. To get Mercury and Venus in a dark sky, you'll have no choice but to photograph them when they are low in the morning or evening sky. This makes them particularly difficult subjects. An alternative for Venus is to track it down in the daytime sky, either by using setting circles or by continuing to track Venus after you've observed it in morning twilight. Despite the fact it is in a blue sky, it is bright enough to show up, and with the greater altitude it can appear much sharper.

With Mars and the other outer planets you are not tied to evening and morning twilight. For a few weeks or months each year (or in the case of Mars, every two years), these planets can be seen high above the horizon in a dark sky. The best time to observe an outer planet is when it is near opposition. This is also the period when the planet is closest to Earth and the disk is largest.

Finding and Focusing Your Target

With the high power of eyepiece projection, the field of view is very narrow. Finding the target and centering it in the small field can be a challenge in itself. To make the job a little easier, align your finder scope with the main optical tube. The alignment should be as accurate as possible. Before attaching your camera make sure that the object is centered in the eyepiece. Once you attach the camera and adapter, use your finder to bring the object into the field.

Focusing is the most critical part of eyepiece projection photography. A highly magnified image viewed through the camera will look grainy or fuzzy at best, not like the view through the eyepiece alone. To focus, concentrate very carefully on one part of the image and make gradual adjustments to the focus knob until the image is as sharp, or least fuzzy, as possible. Do not try to use split-image or microprism

What's My Exposure?

Another simple formula will help you determine the best exposure for your subject:

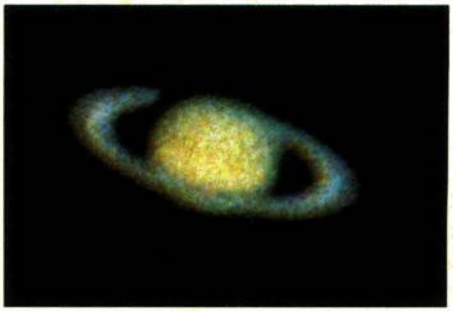
$$\text{Exposure Time (in seconds)} = f^2/(S \times B)$$

where f is the f/ratio of the telescope during eyepiece projection, S is the ISO speed of the film, and B is the relative brightness of the object photographed. The relative brightness is a number assigned to each object. It takes into account several factors, such as the magnitude of the object, its surface brightness, and film reciprocity failure. It is based on actual photos.

Object	B Value
Sun (with full aperture filter)	80
Moon (Full)	200
Moon (Gibbous)	80
Moon (Quarter)	40
Moon (Crescent)	10
Mercury	60
Venus	400
Mars	60
Jupiter	30
Saturn	10
Uranus	4

With an 8-inch Schmidt-Cassegrain telescope and a 10mm eyepiece, the effective f/ratio was f/155 (see *Calculating Your Power*, page 61). Say we want to take a picture of Saturn using ISO 200 film. First take the f/ratio of 155 and square it to get 24,025. Multiply the film speed of 200 by Saturn's relative brightness value of 10. This yields 2,000. Divide 24,025 by 2,000 to get 12, which is the correct exposure time in seconds. Twelve seconds is quite long, so you may wish to go to ISO 400 film to cut the exposure to only 6 seconds.

These calculated values are only approximate. Always take longer and shorter exposures in addition to the calculated exposure to pinpoint the best exposure time.



SHOOTING SMALL and blowing up the image is one way to keep planetary exposures short. Scott Rosen used an effective focal length of only 5900mm and a 2-second exposure to record Saturn on ISO 400 film. He then magnified the image in a slide duplicator.

OVEREXPOSING A PLANET will wash out disk details but may pick up some moons. In 1980 Rick Albrecht used an 8-second exposure with a Celestron 14 at f/70 on ISO 800 film to photograph Saturn with its rings edge-on. Saturn is overexposed but Titan, its largest moon, was recorded to the right of the planet.

screens. At high magnifications and long focal lengths these focusing areas will black out.

If your camera has interchangeable focusing screens, try a fine ground-glass screen or one with a clear center spot. The Beattie Intenscreens are also good since they produce a brighter image than regular ground-glass focusing screens.

A focusing magnifier that clips onto your camera viewfinder can help you zero in on the point of best focus. Focus magnifiers are available for most brands of cameras. Another focusing aid is an electric focus motor for your telescope. These avoid the bouncy images that come from touching the telescope when focusing manually. It is always a good idea to check the focus after each exposure since the seeing conditions can change or the focus may simply shift.

Once you have located the object and focused on it, monitor your target for a few minutes. Ideally the planet should stay in the same place within the field. However, if your telescope is not properly balanced or polar aligned, or if the drive is not tracking accurately, your target will drift off center. If it drifts in right ascension and you have a drive corrector, you can use the speed knob to slightly increase or decrease the tracking rate of the drive.

Tricks of the Trade

Because of the long effective focal lengths, the smallest vibrations or breaths of wind will jostle the image. Even releasing the shutter of your camera produces enough vibration to smear the planet. To avoid the wind, only shoot on calm nights. To avoid shutter vibration, use the hat trick. Hold a black card in front of the telescope. With the camera's shutter on B, lock it open and wait a few seconds for the vibration to die down, then quickly snap the black card out of the way to expose the film. Once the exposure is completed, whip the card back and close the camera shutter. Always hold the card an inch or two in front of the telescope. To avoid blurring the image with your body heat, stand to one side of the telescope tube.

As a final tip, if your camera has an electronic shutter make sure you have fresh batteries. Opening the shutter frequently and for extended periods can drain the batteries leaving you with a dead camera.

The key to successful planetary portraits is to be persistent. It may take several rolls of film before you get results you're happy with. Even when everything goes just right there will often be one exposure on a roll that is a little better than the rest. At every shooting session be prepared to burn off a 36-exposure roll. The more photos you take, the better you'll get. The final result will be a gallery of planetary portraits to be proud of. □

Mark J. Coco is a technical writer and amateur astronomer living in southern California. His last article, co-authored with Steve Edberg, was "How to Get Started in Piggyback Astrophotography" in the November 1985 issue.

A Journey into Darkness

Where will you be on July 11, 1991? If you want to be watching the total solar eclipse of the decade, don't wait any longer to make your travel plans.

by Alan Dyer

The excitement has been building for over a year. These days if you get any group of amateur astronomers together their conversation soon turns to *The Eclipse.* "Where are you going for the eclipse?" people ask each other. "Are you going to Hawaii or Mexico?" Then the rumors start. "I've heard everything's sold out already. All the rental cars on Hawaii are booked up." With stories like these making the rounds, many people may have given up hope of seeing the 1991 eclipse. But are the rumors true?

We discovered that although hotels and rental cars have been heavily booked at the prime viewing sites, tour packagers still have space available. But you'll have to move fast if you want to be in the path of totality a year from now.

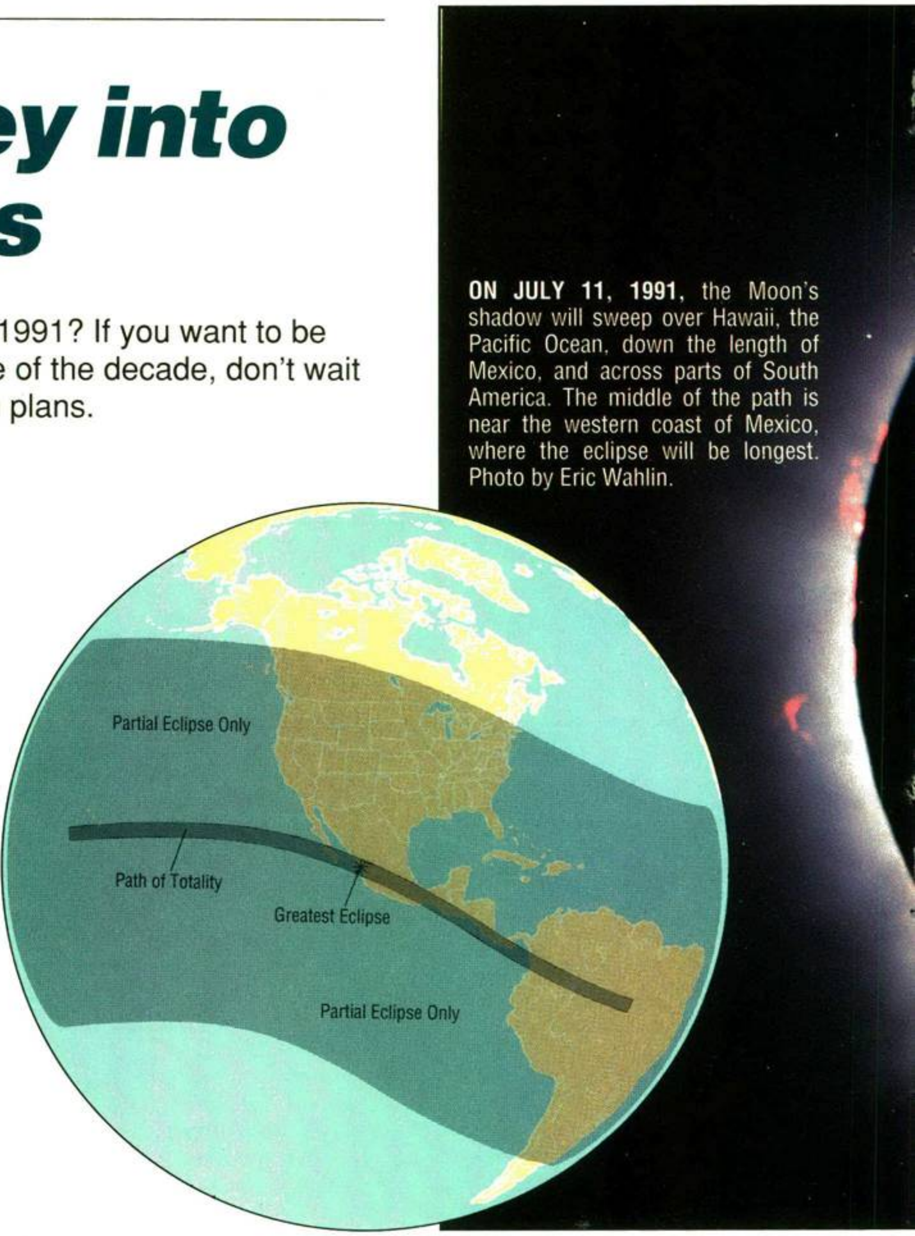
The Eclipse of the Decade

The 1991 eclipse is generating more interest than all the eclipses of the last decade combined. "I've never seen this kind of fervor before for an eclipse," says Joel Harris, a veteran of ten solar eclipses. "On a scale of one to ten, this eclipse measures a thirteen!"

The reason for the excitement is the almost ideal viewing circumstances. On July 11, 1991, the narrow path of totality will sweep over Hawaii, the eastern Pacific Ocean, across the tip of the Baja peninsula, and then down the length of Mexico. At the mid-eclipse point near Tuxpan on the west coast of Mexico, eclipse watchers will be able to revel in nearly seven minutes of totality. Not since 1973 has there been an eclipse as long as this one, and it will be the year 2132 before we get another seven-minute-long "monster eclipse."

The other attraction is that this is the first total eclipse since 1979 to cross any part of the North American continent. "This one's literally in our backyard," as Harris put it. Then there's the weather. The chances of clear skies at the prime viewing sites are the best of any recent eclipse, up to 90 percent for sites like the Baja and Hawaii's Kona Coast.

Combine all these factors — the decade-long drought of Western Hemisphere eclipses, the long totality, the clear sky chances, observing sites packed with first-class tourist facilities — and you can see why this eclipse is creating so much interest. You'd have a tough time designing a better eclipse, except for one thing: the two land sites with the clearest skies are extremely small. One is an island, Hawaii, and the other is the tip of a 1,000-mile-long peninsula, Baja, both of which are separated from the rest of the world by transportation bottlenecks. Tens of thousands of people will be crowding onto those tiny bits of land, taxing facilities beyond the limit of capacity.



ON JULY 11, 1991, the Moon's shadow will sweep over Hawaii, the Pacific Ocean, down the length of Mexico, and across parts of South America. The middle of the path is near the western coast of Mexico, where the eclipse will be longest. Photo by Eric Wahlin.

"Aloha" or "Buenos Dias"?

Once you've decided that you're not going to miss this eclipse, your first task is to choose between Mexico and Hawaii. For Americans and Canadians, Hawaii poses fewer travel hassles: no permits, tourist cards, foreign currency, or special insurance. On the other hand, it's possible to drive to Mexico — the first opportunity since 1979 for North Americans to drive to a total eclipse.

In Hawaii the eclipse occurs at 7:30 in the morning; in Baja and western Mexico it happens at high noon. The eclipse is also shorter in Hawaii, just over four minutes if you

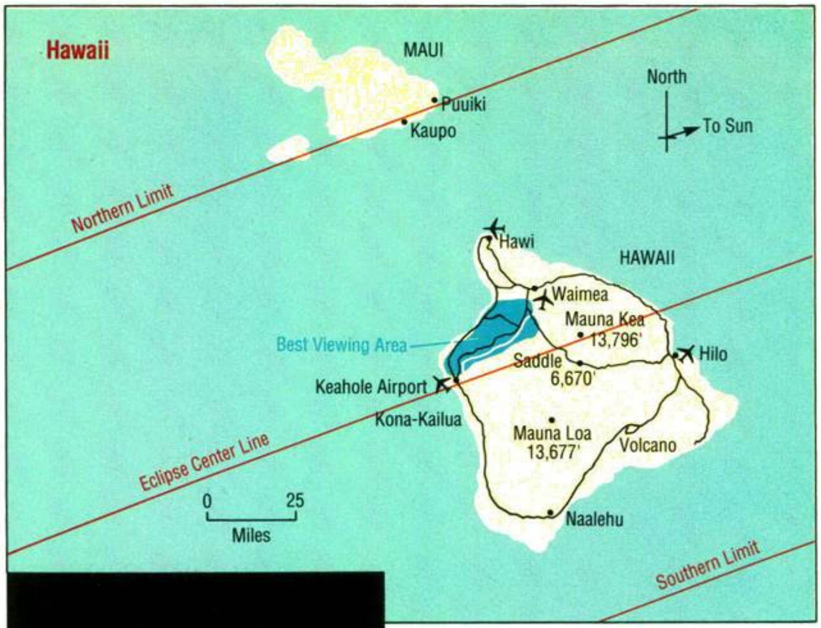
are on the center line. This is longer than most of the eclipses in the 1980s, however.

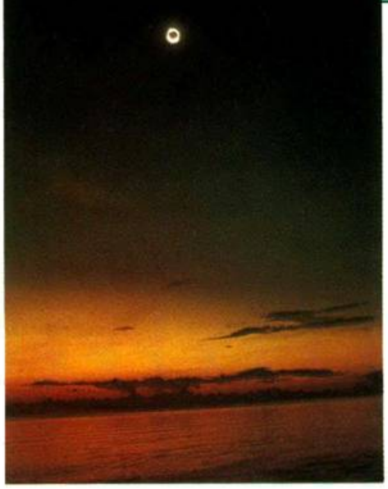
At eclipse time in Hawaii the Sun will be 21° above the east-northeastern horizon, but only 8° high at the start of the partial phase at 6:30 a.m. This shouldn't be a problem, however. In fact it will provide some excellent photo opportunities with the eclipsed Sun over a landscape or seascape.

If you're seeking the maximum length of totality, then Baja or the west coast of Mexico is the place to be. From those sites totality will last almost seven minutes, a luxurious amount of time to take pictures, view the eclipsed Sun through binoculars, and look around at other sky phenomena. However, since the Sun will be almost directly over-

Choose Your Site

Location	Duration of Totality	Local Time	Sun Altitude	Sun Azimuth
Hawaiian Islands				
Hawi, Hawaii	3m35s	7h28.5m	21°	73°
Hilo, Hawaii	4m07s	7h28.4m	22°	73°
Kailua-Kona, Hawaii	4m09s	7h27.8m	21°	73°
Kaupo, Maui	1m11s	7h29.6m	21°	73°
Mauna Kea Obs., Hawaii	4m12s	7h28.1m	22°	73°
Naalehu, Hawaii	3m14s	7h29.3m	21°	73°
Puuiki, Maui	0m14s	7h30.3m	21°	73°
Volcano, Hawaii	3m49s	7h28.3m	21°	73°
Waimea, Hawaii	4m09s	7h28.4m	22°	73°
Baja				
La Paz	6m27s	11h47.6m	82°	102°
San Jose del Cabo	6m25s	11h50.1m	83°	96°
Santiago	6m57s	11h49.2m	83°	99°
Villa Constitucion	4m20s	11h44.5m	79°	103°
Villa Insurgentes	2m16s	11h45.1m	79°	104°
Mexican Mainland				
Guadalajara	6m18s	13h09.2m	87°	295°
Mazatlán	5m41s	11h58.8m	88°	116°
Mexico City	6m42s	13h20.9m	80°	287°
Oaxaca	5m36s	13h30.4m	75°	292°
Puebla	6m27s	13h23.8m	78°	287°
Tuxpan	6m56s	12h02.4m	90°	100°





TOTALITY WILL REACH Hawaii in the early morning with the path encompassing the island of Hawaii and grazing the south coast of Maui. The Sun will be 21° high, giving a view similar to Carter Roberts' photo of the March 18, 1988, Indonesian eclipse.

head, you'll have to strain your neck to look at it. Some telescopes have problems aiming straight up, and camera viewfinders may be awkward to look through. Except for a fisheye shot, it will be impossible to include a landscape in wide-angle shots of the eclipsed Sun, limiting the creative photo opportunities.

But what about the weather? The Big Island of Hawaii is an island of contrasts. The island's east side is often cloudy and wet. During July the city of Hilo typically enjoys only two or three clear days. The west side of the island, called the Kona Coast, is usually the leeward side; the skies are clear twenty to twenty-five days during July. Jay Anderson, a senior meteorologist for Environment Canada, puts it well: "In nearly twelve years of forecasting weather for eclipses, *the west side of Hawaii* is as close to a sure thing as I've ever seen." While clouds usually build in the afternoon, the mornings are almost always clear. With those kind of odds, everyone will be congregating in Kona. As Ray Fabre of the Hawaiian Astronomical Society quipped, "One side of the island is going to tilt over!"

For Baja the chances of clear weather are similar to Hawaii, about 80 to 90 percent, but there is a catch. July is the rainy season on the mainland of Mexico. Thunderstorms form each day over the west coast mountains. According to Anderson, "At night easterly winds often catch this cloud and push it across the Gulf of California and onto the Baja peninsula. By noon the cloud cover has usually disappeared, but sometimes the cloud can linger over the entire eclipse area. I found that in past Julys this has happened an average of five days per month." Areas along the coast away from southern Baja's central Santo Lazaro Mountains are least likely to be clouded out, but that's where most people will be anyway since that's where the hotels and roads are.

As with all weather predictions, there are no guarantees. Even in Hawaii or Baja a rare hurricane could swamp eclipse watchers with a torrential downpour. Nevertheless, both locations represent your best bet for seeing the eclipse, *if* you can get to them.

An Island Eclipse

Hawaii is familiar with handling lots of tourists but not eclipses. "We have learned a lot about crowd management from events like the Ironman Triathlon," says Ken Johnson of the Hawaii Tourist Department, "but from all indications the eclipse may have a much greater impact." Most scenarios project that between 10,000 and 30,000 eclipse goers will descend on the island of Hawaii in the days prior to the eclipse. This is over and above the normal non-eclipse tourist population, which is at its peak in July.

There is a limiting factor to the number of people that will get to Hawaii: the number of flights to the Big Island. Most trans-Pacific flights land in Honolulu on the island of Oahu. This means a short flight from Honolulu to the Big Island, preferably into the Keahole Airport near Kona. Aloha Airlines and Hawaiian Air, the two main regional carriers, each schedule between twenty and thirty-five flights a day from Honolulu to Hawaii (either to Kona or Hilo), but both said they will add extra flights if demand warrants. Anyone traveling on their own should make flight reservations as soon as possible. Aloha Airlines is taking reservations now for July 1991. Hawaiian Airlines will accept reservations starting in early August of this year.

If you do get to Hawaii, where do you stay? Island campsites are very limited in size and lack water. Local officials are discouraging campers.

There are about 8,800 hotel rooms on the Big Island, 84 percent of them on the Kona Coast side. If you call any of the major hotels directly you'll get the same line, "Sorry, we're all sold out." That's the bad news. The good news is that most of these rooms have been bought up in huge blocks, sometimes hundreds of rooms at a time, by tour companies and travel agencies. Many of them have yet to resell all their rooms to individuals. In addition, people operating tours told us that in July of this year companies that reserved room blocks will be required to pay substantial deposits to hold onto their rooms. If room speculators don't have the cash due to insufficient advance sales, they may release some of their rooms. So hotel rooms are still available, but don't expect any bargains.

The same is true of rental cars. Normally there are 4,000 rental cars on Hawaii, enough to service the island at peak tourist capacity. For the eclipse the rental car agencies will be shipping more cars to the island. Despite the fact that rental car companies don't take reservations more than a year in advance, most of these cars are spoken for already by

Leave the Driving to Us

When you join an organized eclipse tour, someone else worries about the travel details. In places like Hawaii and Baja, tours may be the only way you can guarantee a hotel room. As of early April many tour packagers still had space available. However, in some cases prices are subject to change, since many hotels and airlines have not fixed their 1991 rates.

Note: This information is for planning purposes only. This listing does not represent an endorsement by ASTRONOMY magazine of any of these tour packages.

BAJA

Baja Expeditions
2625 Garnet Avenue
San Diego, CA 92109
(800) 843-6967, or (619) 581-3311
Hotel packages ($1,500) or beach camps ($700).

ITA Tours
P.O. Box 250
Somerville, MA 02145
Daniel Cugno (617) 776-4292
July 7-14. Flight from Boston to La Paz. $1,100-$1,500.

Oceanic Society Expeditions
Fort Mason Center, Building E
San Francisco, CA 94123
(800) 326-7491
July 8-13. A camping expedition. $700 (approx.). Does not include air fare.

Research Amateur Astronomy Symposium
P.O. Box 16542
San Francisco, CA 94116
July 8-12. A conference in La Paz that includes a room along with the $130 conference registration.

Royal Astronomical Society of Canada
441 Davisville Avenue
Toronto, Ontario, Canada
M4S 1H7
Michael Watson (416) 483-4664
Two-day trip from Toronto flying to Los Cabos Airport eclipse morning. About $1,000 Canadian.

Scientific Expeditions, Inc.
1832 Quail Lake Drive
Venice, FL 34292
(800) 344-6867
July 7-12. Flights from various U.S. cities. $1,300 to $1,600. As of April, limited space available.

Toronto Centre, R.A.S.C.
c/o Europa Travel
744 Broadview Avenue
Toronto, Ontario, Canada
M4K 2P1
(416) 465-7489
Ten-day tour of California astronomy sites plus four-night trip to Baja. Depart from Toronto; people can join at Los Angeles. About $2,500 Canadian.

Travelbug International
P.O. Box 178247
San Diego, CA 92117
(800) 247-1900, or (619) 268-8687
July 9-13. Hotel packages in Cabo San Lucas/San Jose del Cabo area. $900-$1,100. Does not include air fare.

Photo by Jacques Guertin.

Twilight Tours
3316 West Chandler Blvd.
Burbank, CA 91505
Joel Harris (818) 841-8245
July 9-16. Flight from Los Angeles to Los Cabos airport. $975.

HAWAII

Bishop Museum
c/o American Express Travel
2222 Kalakaua Ave., 8th Floor
Honolulu, HI 96815
(800) 367-2333
Accommodation and rental car packages. Includes inter-island flight. $600-$1,000.

Momentum Travel
75-5751 Kuakini Hwy., Suite #103
Kailua-Kona, HI 96740
(800) 346-0276
Room packages at Kona Coast hotels. Flight reservations must be made through Momentum Travel.

Scientific Expeditions, Inc.
1832 Quail Lake Drive
Venice, FL 34292
(800) 344-6867
July 7-12. Flights from various U.S. cities. $1,900-$2,100. As of April, limited space available.

Stephen Berr's Science Tour
c/o Rosenbluth Travel
1420 Walnut Street
Philadelphia, PA 19402
(215) 272-7827
July 8-13. Flights from various U.S. cities. $1,500-$1,800.

MAINLAND MEXICO

Alberta Science Centre/ Calgary Centre, R.A.S.C.
c/o Let's Talk Travel Ltd.
110-112 4th Avenue S.W.
Calgary, Alberta, Canada
(800) 661-1335, or (403) 266-0677
Flight from Calgary to Mazatlán on July 10. $750-$1,300 Canadian.

California Academy of Sciences
(in conjunction with Custom Travel Consultants)
2105 Woodside Road
Woodside, CA 94062
Lonnie Baker, California Academy (415) 221-5100, or Custom Travel (415) 369-2105
July 8-12. Flight from San Francisco to Oaxaca, Mexico. $1,050.

Scientific Expeditions, Inc.
1832 Quail Lake Drive
Venice, FL 34292
(800) 344-6867
July 7-12. Flights from various U.S. cities to Mazatlán. $1,300-$1,600.

COSTA RICA

Oceanic Society Expeditions
Fort Mason Center, Building E
San Francisco, CA 94123
(800) 326-7491
July 7-17. Eclipse viewing from a campsite in Santa Rosa National Park. $1,800 (approx.) Does not include air fare.

BRAZIL

Bill Matthias
5236 "A" Cleon Avenue
North Hollywood, CA 91601
(818) 985-9991
July 5-23. An adventure tour of Brazil with eclipse viewing from Tefe, Brazil. $2,772. Includes air fare from Los Angeles to Rio.

Sailing into the Shadow

An alternative way to see the eclipse that avoids the worries of hotel rooms and ground transportation is a cruise, either in the Hawaiian Islands or off the western coast of Mexico. Most cruises offer guest lectures and expert assistance in viewing and photographing the eclipse. In some cases different tour groups are selling spaces on board the same ship.

Note: This information is for planning purposes only. This listing does not represent an endorsement by ASTRONOMY magazine of any of these cruise packages. — *Compiled by Lisa Rohner Schafer*

WATCHING FROM THE DECK of a rolling cruise ship may mean keeping your photographic exposures short, but the view can be every bit as spectacular as from land. Photo of the 1973 Canberra eclipse cruise by Paul Deans.

MEXICAN COAST

Carnival Cruise Lines
Ship: "Jubilee"
July 7-14 from Los Angeles. On eclipse day the ship will be docked in Mazatlán on the west coast of Mexico.

Travelbug International
8369 Vickerson St., Suite W
San Diego, CA 92111
(800) 247-1900
$1,265-$1,465 per person. Air packages available.

Horizon Travel and Tours
6760 University Ave.
San Diego, CA 92115
Roberta Last (619) 287-8880. Lectures by Dennis Mammama, director of the Reuben H. Fleet Space Center; Jon Olson, dean of astronomy at Southwest University, and others. $1,395-$1,595. Includes air fare from most major U.S. cities.

Admiral Cruise Line
Ship: "S.S. Azure Seas"
July 8-15 from Los Angeles. Located at sea during eclipse, as close as possible to the point of longest duration. Lectures by Richard Berry, Editor-in-Chief, ASTRONOMY magazine; Edwin Krupp, director of the Griffith Observatory; David Schramm; and others.

Love To Travel
26847 Grand River Avenue, Suite 16
Detroit, MI 48240
Ed Love (313) 592-8633
$1,695-1,995. Includes air fare from most major U.S. cities.

Adler Planetarium
1300 Lakeshore Drive
Chicago, IL 60605
Jessica MacKinnon (312) 332-0332
$1,500. Includes air fare from most major U.S. cities.

UCLA Extension, Division of Science
P.O. Box 24901
Los Angeles, CA 90024
Karen Prinzmetal (213) 825-7093
$1,200-$1,700. Does not include air fare. UCLA is offering two extension astronomy units for a $250 enrollment fee.

Norwegian Cruise Lines
Ship: "Southward"
July 8-15 from Los Angeles. Located at sea during eclipse, as close as possible to the point of longest duration.

Grouptrav National Inc.
555 Soquel Ave., Suite 130
Santa Cruz, CA 95062
Kathleen Bowen (800) 877-3703
Lectures by Frank Drake and Anthony Aveni. $1,445-$2,400. Does not include air fare. Air fare discounts available.

HAWAIIAN ISLANDS

American Hawaii Cruises
Ship: "S.S. Independence"
July 6-13 from Honolulu. Interisland cruise located at sea during eclipse off the Big Island of Hawaii.

American Hawaii Cruises
550 Kearny Street
San Francisco, CA 94108
(800) 765-7000, or (415) 392-9400
$1,125-$3,895. Does not include air fare.

YTA Travel
115 Lewis Wharf
Boston, MA 02110
Ann Burgess (617) 723-1212.
$1,250-$1,825. Does not include air fare. Air fare discounts available.

YACHT CHARTERS

For anyone looking for a more private viewing of the eclipse or planning a small eclipse party, the perfect answer might be a chartered yacht. For $120-$350 per person per day, groups of two to ten can charter a yacht, complete with crew and provisions.

Ocean Voyages
1709 Bridgeway
Sausalito, CA 94965
Mary Crowley (415) 332-7460

LeBoat Inc.
P.O. Box E
Maywood, NJ 07607
Evelyn Gresser (800) 922-0291

Yacht Charters Worldwide
16340 Martincoit Rd.
Poway, CA 92064
Marta Packard (619) 673-9489

tour companies that want to sell room and car packages. According to Ken Miller of the Bishop Museum, Honolulu, "Ground transportation will be at a premium. The best advice we can give to people is to purchase a room that includes a car."

You may think you won't need a rental car, since if you are anywhere on the Big Island you're in the path of totality. However, locations along the hotel-dotted coast south of downtown Kailua-Kona have restricted sight lines to the rising Sun. From some locations the Sun may not clear the top of the Hualalai or Mauna Loa volcanoes by eclipse time, let alone by the start of the partial phase. You may have to drive north to the Waikaloa or Kohala Coast area or to wherever it's clear that day.

There is one place you definitely will *not* be able to drive to on eclipse day — Mauna Kea. The 14,000-foot dormant volcano bristles with state-of-the-art observatories, but the road to the summit will be closed two days prior to the eclipse. The astronomers' residence area and the Onizuka Interpretive Center at the 9,000-foot level of Mauna Kea will also be closed to the public. "Only the media will be allowed at that site for broadcasting live television coverage," said Karen Rehbock of the University of Hawaii's Institute for Astronomy. The summit area will re-open a day or two after the eclipse. "However," said Rehbock, "we won't be running bus trips to the summit. Individuals and groups wishing to visit the summit after the eclipse will have to rent their own four-wheel drive vehicle or make transportation arrangements with local tour companies."

The road up the other main peak, Mauna Loa, to the solar observatory and weather station at the 11,000-foot level will also be closed. There is even a possibility that the Saddle Road running between Hilo and Waimea will be closed or made one-way. According to Lynn Maunakea, director for research and development for the County of Hawaii, "We're treating July 11, 1991, as a natural disaster. We'll be implementing civil defense plans that may require us to alter traffic patterns." In other words, expect the unexpected.

These sentiments were echoed by Ken Miller: "Just before the eclipse, the island's infrastructure may break down. Everyone will have to stop wherever they are and watch the eclipse as best they can, from hotel rooms, from the side of the road, from airport tarmacs, or perhaps even from aircraft stacked up waiting to land."

The Baja Experience

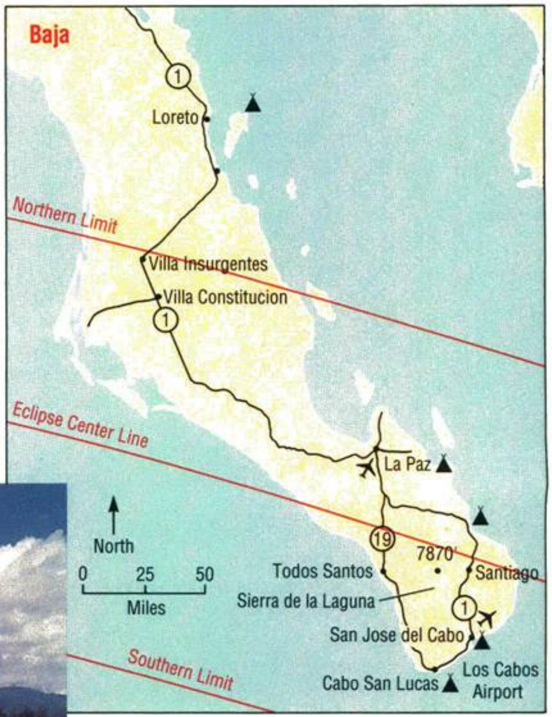
There are about 2,000 hotel rooms in southern Baja and, like Hawaii, they are all reserved. Another 2,000 rooms are scheduled to be added by eclipse time, but even these hotels are booked solid. However, rooms in La Paz, Cabo San Lucas, and San Jose del Cabo are still available through tour packagers, though they may not last long. Private housing may be opened up to help ease the crush, but prices will likely be steep. It will be a seller's market.

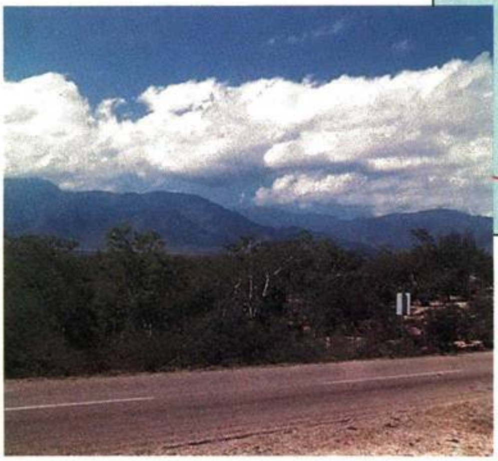
You may be tempted to drive the 1,000-mile trip down the peninsula and seek accommodation as best you can. This is risky. Ted Miller of the Automobile Club of Southern California strongly advises against it. "July is a bad time to drive the Baja. It is a three- or four-day journey along a rough and very tiring road in humid 100°F weather."

While Baja is geared to campers and RVs, the major trade is in the winter. Even so, with the eclipse traffic, campsites and RV parks may fill up. As an alternative, Landon Crumpton, publisher of *Baja Traveler* magazine, points out that "No one owns shoreline property in Baja. It is all public land. Camping anywhere on the beach is a common practice. As for safety, I've been traveling the Baja for fifteen years and I've never had a problem with bandits. I feel safer in Baja than in the streets of San Diego. Any problems that do exist are confined to the border areas." However, the conventional wisdom for driving in Mexico is to never drive at night, camp only in designated sites, never pull off the road to sleep, and never travel alone. If you do decide to drive and camp, remember that it will be extremely hot. Take lots of water, portable shade, and sunscreen.

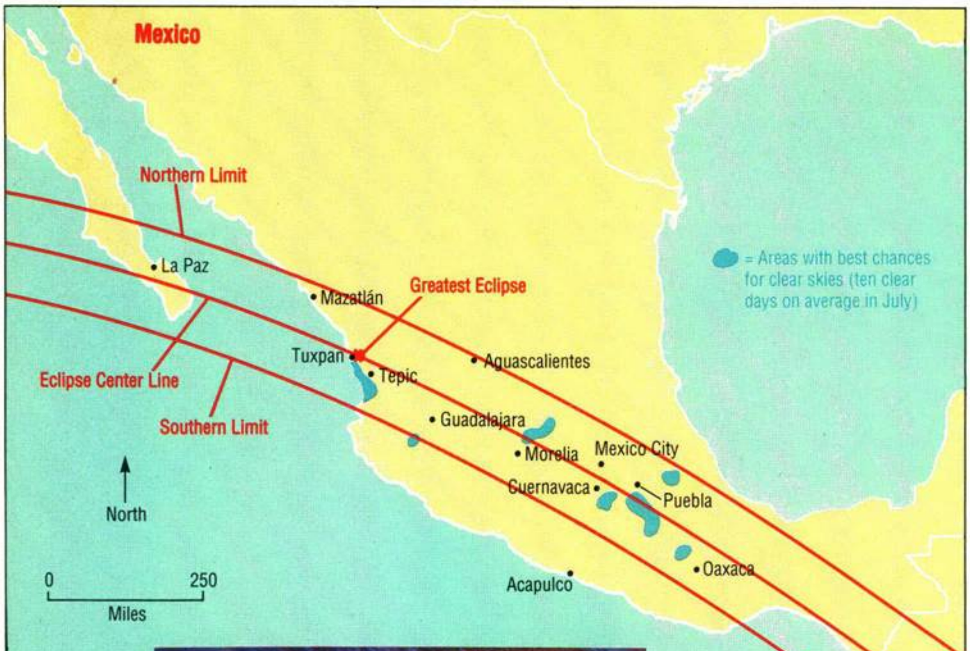
You will also need a funnel. Unleaded gas can be scarce in some places, forcing you to fill up with low-octane Pemex leaded gas using nozzles that are too large to fit most American cars. Continued use of this leaded gas will damage your car. However, Baja and northwestern Mexico cater to American travelers and the availability of 87 octane Pemex Extra unleaded gas in these areas as well as propane is quite good. The longest stretch of highway in Baja between gas stations is 120 miles. Always keep your tank topped up. While there may be a gas station at the next town, there may not be any gas.

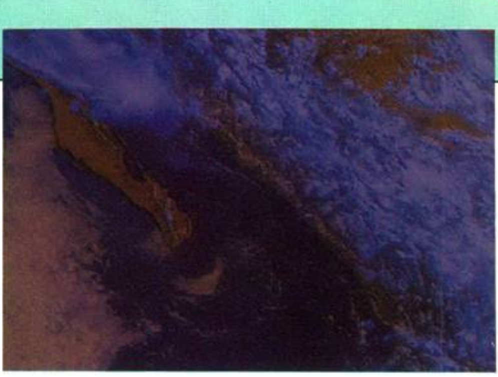
To help stranded tourists, the Mexican government operates a road service called the Green Angels. Their trained drivers patrol the major highways twice a day during daylight hours rendering basic service and first aid. According to Lourdes Ebrard of the Mexican Tourist Commission in Los Angeles, "We will be adding extra patrols for the eclipse." In addition, Ebrard is assembling an overall plan that will help the Mexican government handle the many other problems the eclipse will bring.





THE NEXT LANDFALL will be the southern tip of the Baja peninsula where the eclipsed Sun will be nearly overhead in the sweltering heat of midday. Photo of the Los Cabos area by Joel Harris.





A TYPICAL JULY DAY in Mexico shows clouds over mainland Mexico but clear skies rimming the west coast, especially south of Mazatlán. The only cloud in southern Baja is over the central spine of the Santo Lazaro Mountains. GOES satellite image courtesy of Jay Anderson.

For example, how difficult will it be for thousands of last minute eclipse goers with all their cameras and telescopes to pass through Mexican customs? Also, with some three hundred landing strips in the Baja, many people may opt for flying light aircraft to the path. How will the local authorities handle the increased air traffic? The Mexican government officials we contacted had identified these problems but had not yet devised policies to handle them.

For people driving down from the central or eastern United States, the ferry links between mainland Mexico and the Baja may look like inviting shortcuts. However, every experienced Baja traveler we spoke to advised against depending on the ferries. "The Mexican government is purposely discouraging tourists from taking the ferries by hiking prices" said Crumpton. "I've seen some fares quintuple over six months to upwards of $600 for an RV." With the economic growth of Baja, ferries are needed as much as possible for freight traffic; passenger vehicles can get bumped at the last minute.

No matter which route you take, plan to arrive well in advance of eclipse day. On July 11, the last one hundred miles of the Baja highway could be one big traffic jam.

Avoid the Crowds

With all the hype and hassles associated with Hawaii and Baja, you may wonder if there are other options. After all, the eclipse path covers a long swath. One option is watching the eclipse from the sea. As of April many cruise ship companies still had space available. (See "Sailing Into the Shadow," page 72.)

After Baja and Hawaii the best land site is the Mazatlán area of the Mexican west coast. Mazatlán is a city of 250,000 people, twice the population of La Paz in Baja, with a well-established tourist industry. The clearest sites are likely to be south of Mazatlán on the center line near Tuxpan. The July weather statistics for this area show at most ten days a month with clear skies, but "a good sea breeze could keep most of the clouds over the inland mountains, keeping the overhead sky clear," reported Jay Anderson.

As you go farther inland, cloud cover thickens. While the path crosses major cities like Guadalajara and Mexico City, their clear sky chances are only 10 percent. This is unfortunate, since near Mexico City are the Pyramids of the Sun and Moon at Teotihuacan, surely a dramatic location from which to watch a solar eclipse. However, pockets of clear skies can often be found between the mountains, such as southwest of Guadalajara near the southern limit of the path, southwest of Puebla, and in the valley between Puebla and Oaxaca. The key here is to remain mobile.

On average, conditions through Central America and Colombia are even worse. With the eclipse there occurring in mid- to late afternoon, the buildup of tropical thunderstorms is likely. The eclipse path sweeps across the Amazon and central Brazil but, contrary to what you might think, sky conditions at these sites are expected to be good, though the eclipse occurs at sunset and the sites are very remote.

A final option, one that few people have considered, is Maui. The eclipse path just touches this popular Hawaiian island. The extreme southern tip of Maui around Kaupo Village will experience about 50 seconds of totality. The catch is you'll have to rent a four-wheel drive vehicle to get to Maui's south coast.

If you are wondering about the view from the summit of Maui's Haleakala volcano, the eclipse won't be total there. At mid-eclipse the Sun will be reduced to a sliver of a crescent only 5.5 arcseconds wide. In the clear skies at the 10,000-foot altitude it may be possible to see traces of the corona, but the sight still won't begin to compare with the view of totality from across the straits on the Big Island.

Is It Worth It?

Every time an eclipse comes up, people ask themselves, "Are the few minutes of totality worth all the expense and effort? I've seen partial eclipses. Aren't they the same thing?" No. Until you've seen a total eclipse, it's difficult to imagine the dramatic impact of watching the Sun disappear completely from the sky. While it may only last a few minutes, it is a few minutes of your life you will constantly want to relive.

While we can't recommend the single best place to watch the 1991 eclipse nor the best way to get there, we do strongly recommend that you make the effort. Contact one of the tour companies, cruise lines, or your local travel agent. If you miss next year's eclipse it may be a very long time before you get a chance at another. ☐

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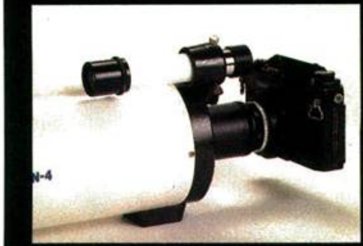

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Scanning the Scutum Starcloud

Rich in dazzling star clusters and challenging nebulae,
the Scutum starcloud offers many delights for summertime observers.

by Phil Harrington

It is absolutely the gem of the Milky Way," said the great observer Edward Emerson Barnard, referring to his favorite part of the Milky Way, the magnificently rich Scutum starcloud. Following the star-studded plane of the Galaxy southward from Cygnus through Aquila and on toward Sagittarius, the Scutum cloud is an immediate standout. The constellation itself is not particularly bright or large, but the milky glow centered on the four stars that make up the Shield is eye catching under a dark sky.

The easy visibility of the Scutum starcloud is caused by a contrast effect. The starcloud is simply a rich region of unresolved stars — a prominent portion of the Milky Way cut off by dark bands of dust.

If Scutum is the gem of the Milky Way, then **M11** (NGC 6705) is Scutum's crown jewel. Called the Wild Duck cluster because its richness and triangular shape resembled a flock of ducks in flight to early observers, M11 is a magnificent sight through binoculars and telescopes and is one of the prettiest open clusters in the sky.

M11 was first sighted by Gottfried Kirch of the Berlin Observatory in 1681. Kirch described the cluster as a "small, obscure spot with a star shining through." Eighty-three years later French comet hunter Charles Messier saw the object and called it "a cluster of a great number of small stars. In a three-foot [focal length] instrument it looks like a comet." William Herschel thought the stars of M11 appeared "divided into five or six groups," an opinion echoed by D'Arrest.

Any search for M11 should start at the star Lambda (λ) Aquilae. While viewing through a finder scope or binoculars, curve to the southwest past 4th-magnitude Iota (ι) Aquilae to Eta Scuti. Continuing westward you will arrive at a crooked rectangle of 6th- and 7th-magnitude stars. M11 lies less than 1° southeast of this rectangle. Because it shines at magnitude 5.8, M11 will be immediately visible in your finder scope. Once you've located the cluster you may even be able to make it out with the naked eye under a perfectly black sky.

Through finder scopes and low-power binoculars M11 reveals a bright, unresolved glow highlighted by an 8th-magnitude orange star near its center. A 6-inch telescope at 50x shows M11 as a collection of dozens of glowing pinpoints spread across 14'. Except for the lone central star, the members of M11 glow at 11th-magnitude or fainter.

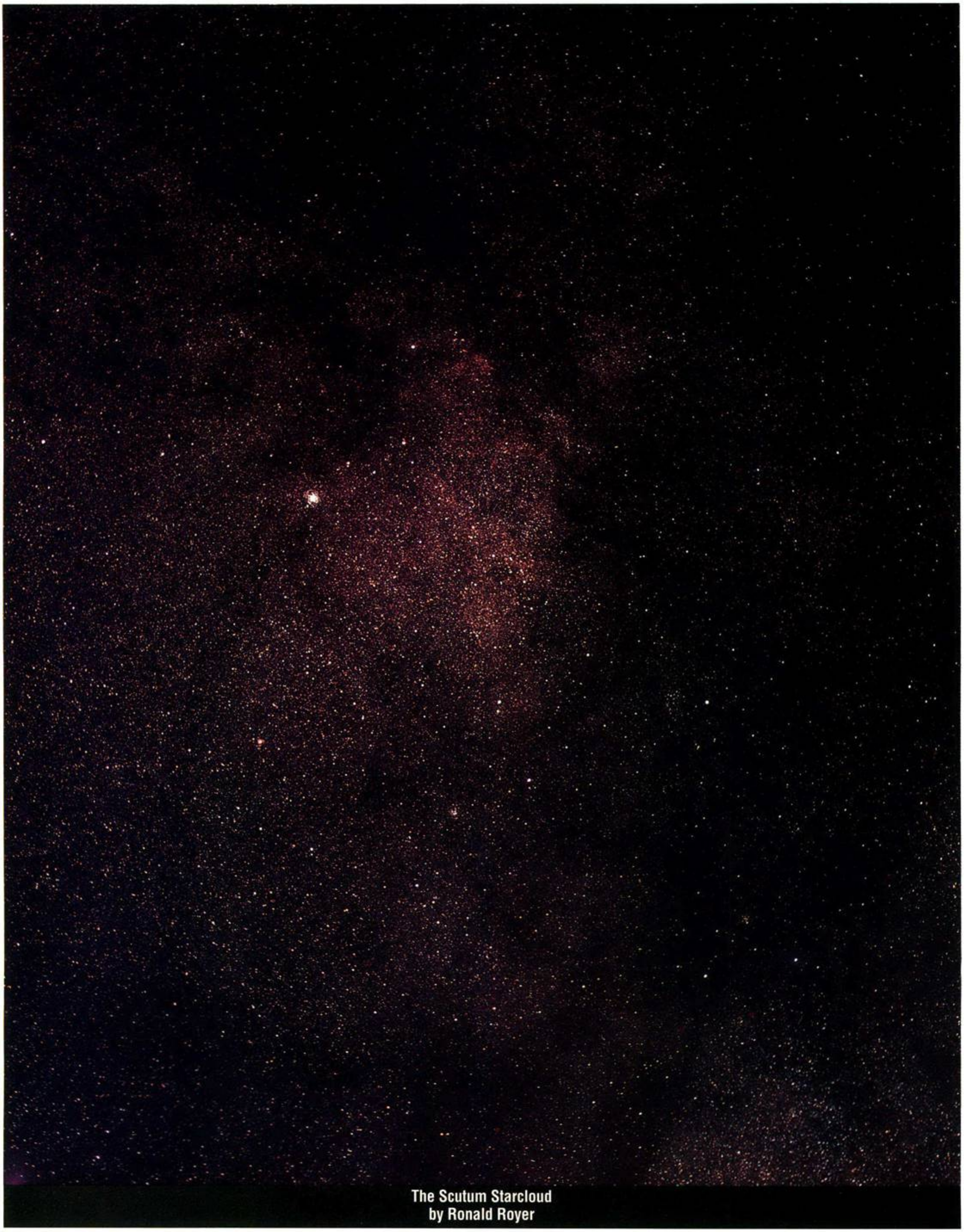
At first glance M11 may appear so rich that it looks like a globular cluster. A closer look reveals M11 is lopsided. The cluster's brightest stars are shaped in a distinctive arrowhead pattern that eighteenth-century English observer William Smyth noted in his classic catalog of deep-sky objects. Smyth wrote that M11 resembles "a flight of wild ducks."

Large telescopes and high powers resolve the core of M11. A 13-inch reflector at 100x shows a breathtaking view of a field strewn with hundreds of stars, each slightly bluish white.

Of the many dark nebulae that surround M11, **B111** and **B119a** are the most obvious. They are visible north of M11 as large, kidney-shaped patches almost touching each other at their southern tips. Although visually these nebulae appear to be nearly identical in size, photographs show that B111 is actually twice as large as B119a. Adding to the area's attractiveness is a "peninsula" of half a dozen 8th- to 10th-magnitude stars wedged between the nebulae.

After you've observed the two dark nebulae, move back to the northwesternmost star in the small rectangle

M11
Magnitude 5.8 Size 14' by George R. Viscome



The Scutum Starcloud
by Ronald Royer

NGC 6712 and IC 1295
Magnitudes 8.2 and 15.0 Sizes 7.2' and 86" by Martin C. Germano

M26
Magnitude 8.0 Size 15' by Lee C. Coombs

near M11. This is **R Scuti**, a bright example of the RV Tauri class of pulsating variable stars. RV Tauri stars are famous for vacillating irregularly between shallow and deep brightness minima. The difference between two succeeding dips in brightness may be as great as three or four magnitudes.

In the case of R Scuti, the star's brightness typically alternates between 5th and 6th magnitude over 140 days. At the same time its spectral classification fluctuates between *type-G5 and* type-K. A secondary period causes R Scuti to drop to about magnitude 8.2 every fourth or fifth cycle. This complex behavior is thought to be caused by differing rates of expansion and contraction by each of the star's many internal layers.

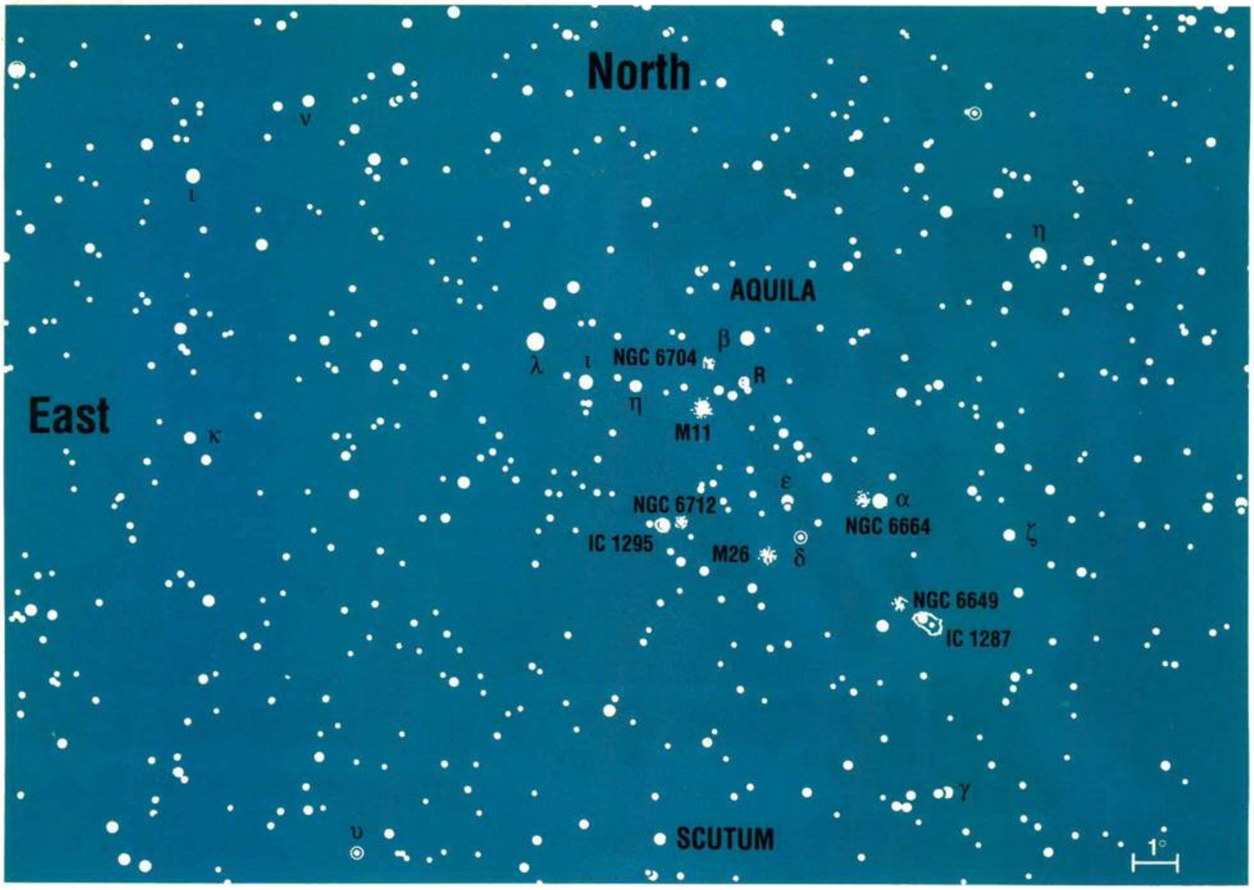
Open cluster **NGC 6704** has always struck me as a sort of poor man's M11. Located 1° north of its impressive neighbor, NGC 6704 is visible in small telescopes only as a hazy smudge of light. A 6-inch scope is the smallest aperture that resolves the brighter stars in this tightly packed open cluster. Viewed through large backyard telescopes, NGC 6704 shows numerous stars sprinkled across a 6'-diameter.

Now move 4.5° southwest of M11 to the 4th-magnitude star Alpha (α) Scuti. Alpha is an excellent jumping-off point for starhoppers searching for nearby treasures. If you switch to your widest field eyepiece and center your attention on Alpha, our next target might just make it into the view.

NGC 6664 is a pretty open cluster found less than a Moon's diameter east of Alpha Scuti. Binoculars and small telescopes reveal a soft, irregular blur highlighted by a single 10th-magnitude star. Six-inch and larger instruments begin to reveal many more stars, most forming a pattern resembling the letter "U." NGC 6664 is thought to consist of approximately fifty luminous type-B stars.

Extending for over half a degree around Struve 2325 is the faint reflection nebula **IC 1287**. To see this object you must use superlative optics on a very transparent night. I have glimpsed this nebula on rare occasions through my 13-inch reflector as a homogeneous, oval glow.

NGC 6649 resides 45' northeast of IC 1287. A little-observed open cluster, NGC 6649 is populated by some fifty stars spread across 6'. None of these stars shines brighter than magnitude 11.6, although a 9th-magnitude field star is superimposed on the cluster's



Deep-Sky Objects in Scutum

Object	R.A. (2000.0)	Dec.	Mag.	Size
IC 1287	18h31.3m	–10°50'	—	44' by 34'
NGC 6649	18h33.5m	–10°24'	8.9	6'
NGC 6664	18h36.7m	–08°13'	7.8	16'
M26	18h45.2m	–09°24'	8.0	15'
R Scuti	18h47.5m	–05°42'	4.5-8.2	140d
NGC 6704	18h50.9m	–05°12'	9.2	6'
B111/119a	18h51:	–5°:	—	120' by 120'
M11	18h51.1m	–06°16'	5.8	14'
NGC 6712	18h53.1m	–08°42'	8.2	7.2'
IC 1295	18h54.6m	–08°50'	15.0_P	86"

Object: Designation in Messier, NGC, or other catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude; subscript P denotes photographic magnitude. **Size:** Diameter in arcminutes or arcseconds; period in days for variable stars.

southwestern border. In an 8-inch telescope this cluster appears like a coarse, oval glow that is best seen at lower magnifications.

M26 (NGC 6694) is a rich open cluster populated by thirty stars of magnitude 10.3 and fainter. Most blend into a nebulous glow through small telescopes, with only about four or five points of light clearly seen in 4-inch scopes. Tripling the aperture increases the number of resolved stars to about two dozen spread over a hazy background glow.

Once you have examined M26, pause and let the stars drift across your eyepiece field for seven minutes. Peek through your finder scope and you'll find three 6th-magnitude stars that form a slightly crooked row. Switching to your main instrument, gently nudge the telescope northward about 1° to find **NGC 6712**. It's a wonder that Messier missed this magnitude 8.2 globular cluster in his survey of the area. You might be able to pick up its dim glimmer through 7x50 binoculars on dark nights. The cluster's relatively loose structure permits partial resolution through 4-inch telescopes; larger instruments hint at the irregular structure of the cluster's nucleus.

Shifting about one eyepiece field to the east of NGC 6712, we encounter the planetary nebula **IC 1295**. Although many catalogs list this object as having a very low surface brightness, I found it easily visible in an 8-inch reflector. Moderate powers revealed a slightly oval disk highlighted by a brighter center. Little additional detail is visible through larger instruments, but long-exposure photographs record a 17th-magnitude central star along with the nebula's subtle ring-like structure.

It's easy to see why Barnard called the Scutum starcloud the "gem of the Milky Way." Few portions of the sky cram so many fine and varied deep-sky objects into so small a zone as does the tiny constellation Scutum. The Scutum cloud shines with a luster unequaled all along the northern Milky Way. ☐

Phil Harrington is an active deep-sky observer from Smithtown, New York. He is a frequent contributor to Deep Sky magazine and is currently writing a book on binocular observing for John Wiley & Sons.

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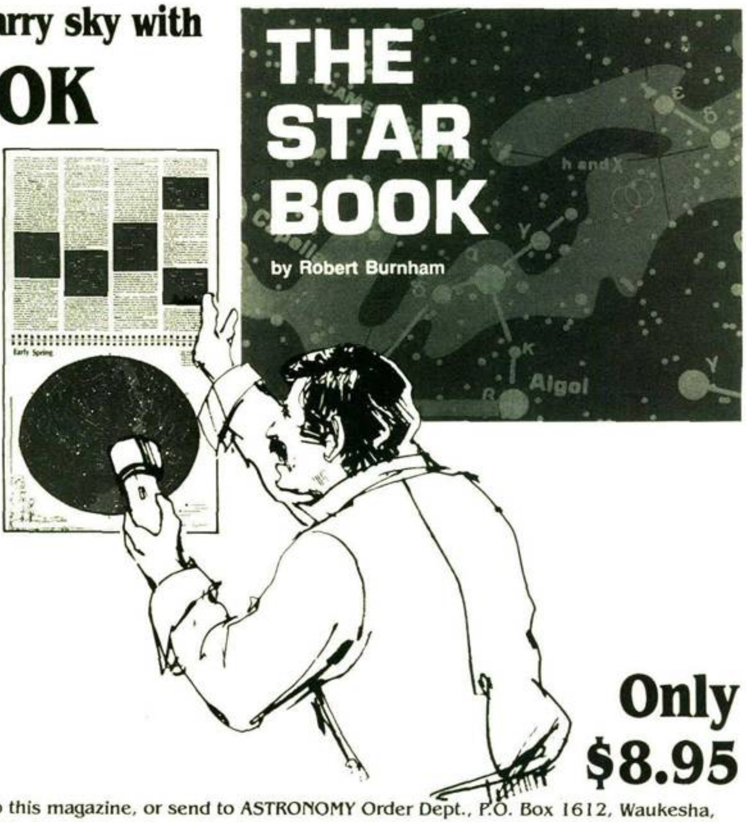

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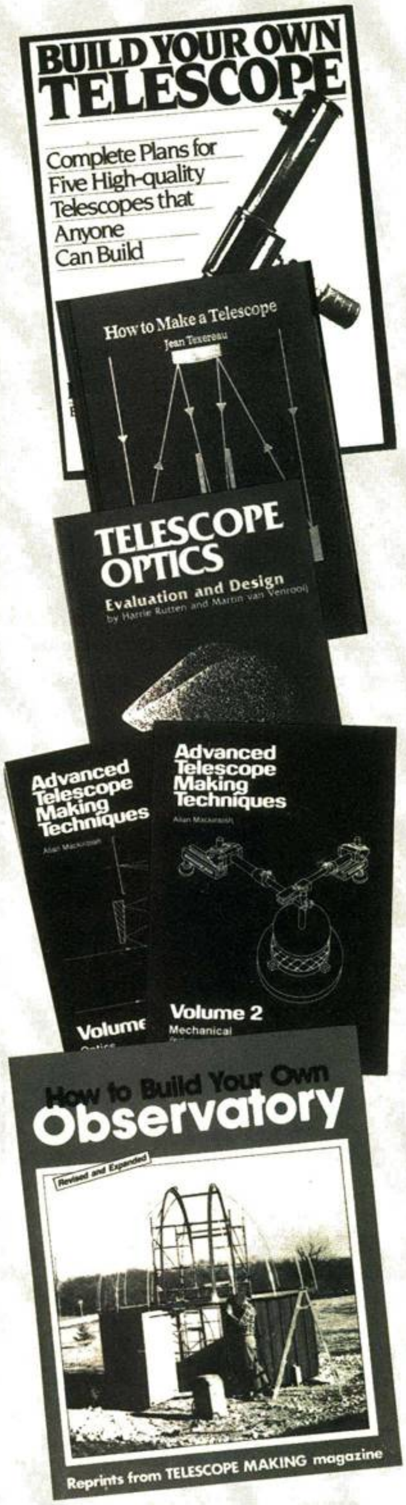
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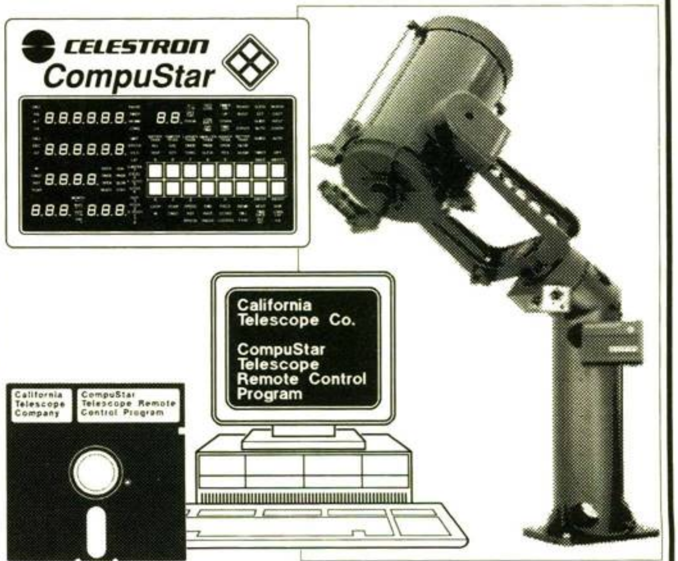
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AN ANNIVERSARY AURORA

"It happened one year ago tonight," said Michael Boschat on March 12, 1990. Boschat was speaking about the incredibly brilliant and active aurora that was visible all across the United States and Canada on March 12, 1989. That auroral storm was visible as far south as southern Florida and northern Mexico. A Canadian observer accustomed to impressive aurorae, Boschat stayed outside of his Halifax home this past March 12 hoping that he would see another great aurora.

"Just after sunset the sky darkened but did not appear quite right," wrote Boschat. "In the western sky I saw a dim red glow that established itself as a ruddy ray of light some 30° by 5° when the sky was truly dark. The northern sky contained a greenish, ray-shaped feature spanning 25° by 3°. Near the zenith lay a nearly blood red coronal arc. The aurora reminded me very much of the one that occurred on the same night the previous year. However, this year's began to diminish in intensity more quickly. After thirty minutes of activity, only a dim glow remained in the northern sky."

One week after Boschat's observations were made, Brian Shulist, another Canadian observer, experienced a brilliant aurora. "Three nights stand out in my mind as the finest displays of aurorae," said Shulist. "February 9, 1986; May 6, 1988; and March 12, 1989. Now I can add one more magical night to the list: March 20, 1990."

Shulist witnessed the auroral display from his observing site in Wilno, Ontario. "I intended to spend the moonless hours of the early evening galaxy hunting in Ursa Major. Twilight had not yet ended when I noticed a luminous glow entirely above me but separated from all horizons by about 30°. As twilight ended the glow did not appear to be transforming into a great display, so I was quite annoyed at its interference with my galaxy hunting.

"While I was looking at Jupiter," Shulist continued, "the auroral glow simply exploded. Bright red and green rays stretched upward toward an intense, pulsating corona. The peak activity lasted between 9 and 9:40 p.m. EST and equalled the intensity of the great aurora of March 1989. After 9:40 p.m. the aurora's intensity increased and decreased until about 11 p.m. It was an unforgettable sight!"

AN EERIE GREEN AURORA blanketed the winter sky over Anchorage, Alaska, on March 20. Photo by Scott McGurk.

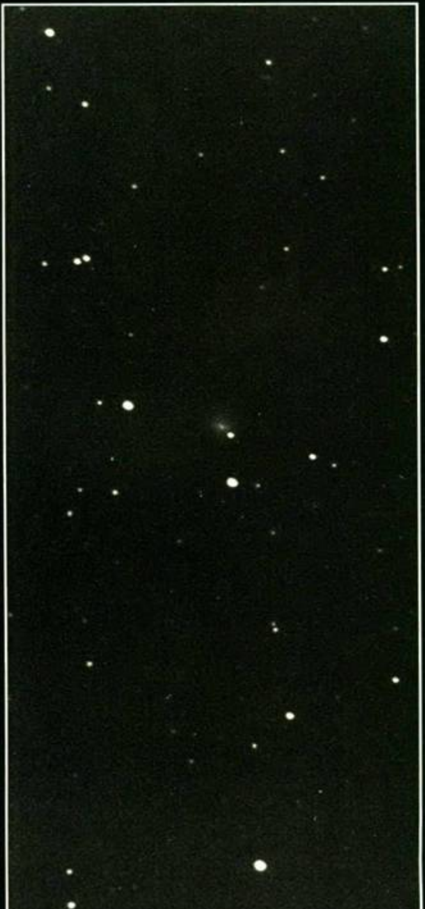
BLAZING BLUE-GREEN STREAMERS characterized the aurora visible over Red Deer, Alberta, Canada, last March. Photo by Bill Tetley.

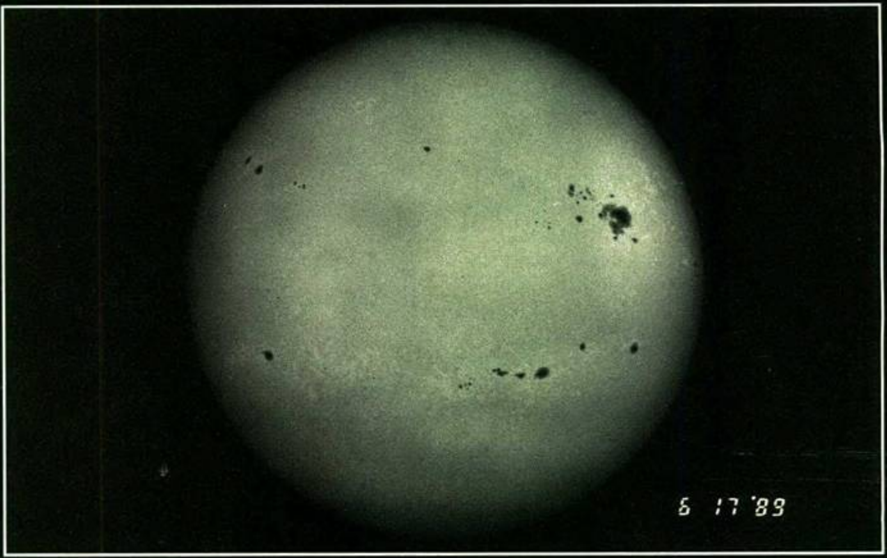
ENHANCE YOUR GALAXIES BY COMPUTER

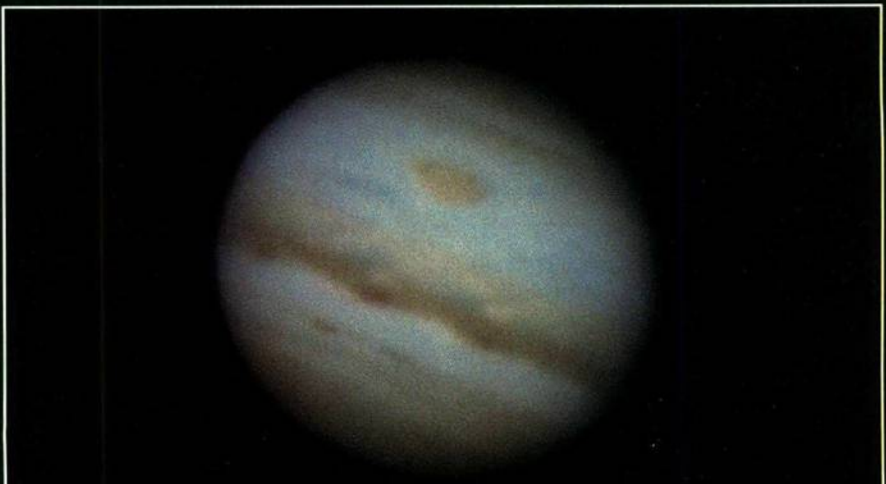
Professional astronomers have long used computers to enhance digitized images of astronomical objects, extracting the most detail possible for study. The growing availability of sophisticated computer and software technology has made image processing possible for small institutions and amateurs as well. George E. Fowler's computer-enhanced photo of the irregular galaxy M82 (opposite page) wins this month's $100 "Best Astrophoto" award. A member of the Tidewater Community College Astronomical Society in Portsmouth, Virginia, Fowler used the college's 14-inch f/11 SCT and STAR I CCD camera to record a 2-minute exposure of the galaxy. He then enhanced the photo by displaying it in false colors that delineate surface brightness levels in the galaxy.

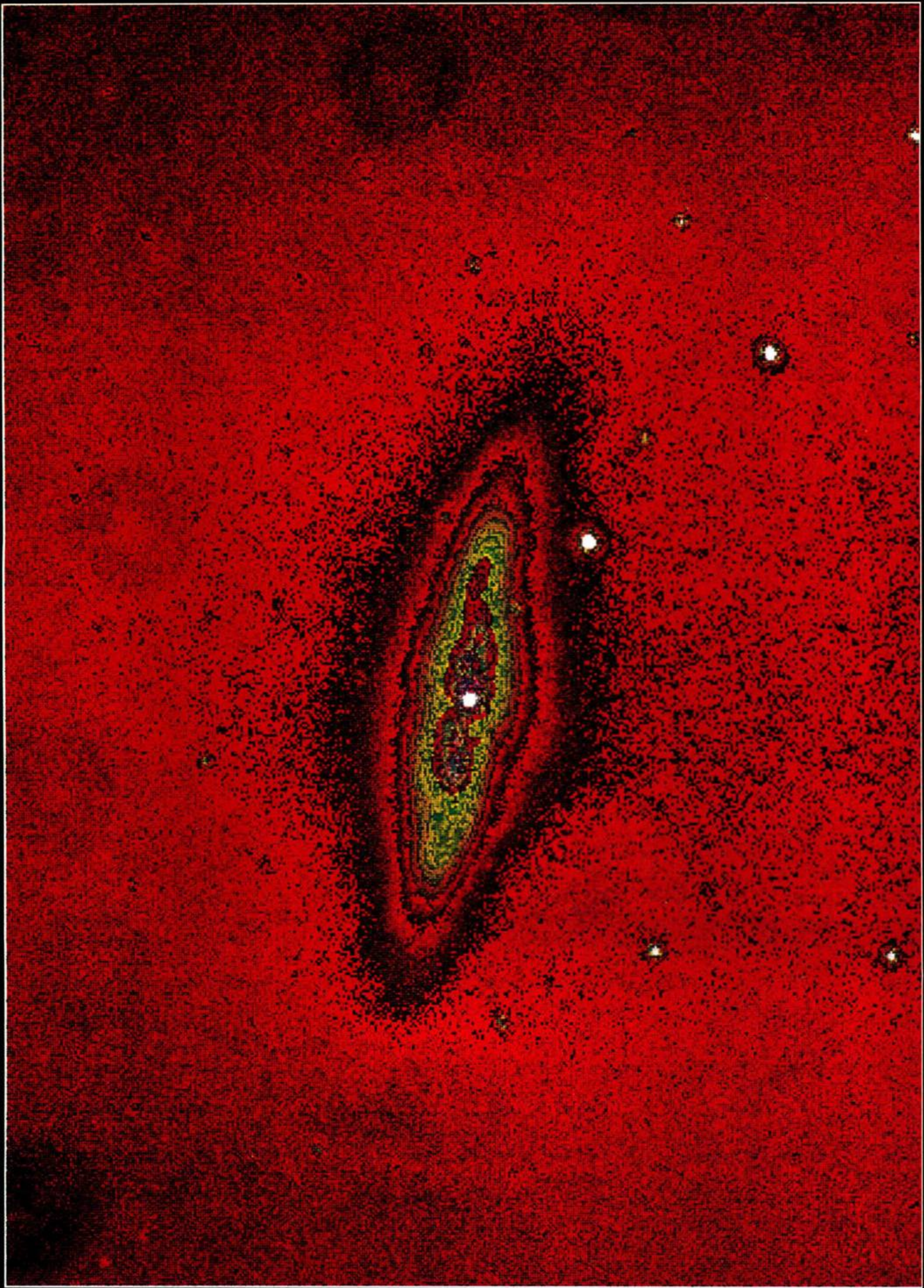
By early spring 1990 Comet Skorichenko-George brightened to binocular visibility, glowing at 9th magnitude. Jeffrey Jones' photo shows the comet on March 24. Another comet, briefly visible at 9th magnitude during March, was Cernis-Kiuchi-Nakamura. Chris Schur's photo shows the comet on March 19 (left).

Solar system observers remained transfixed by atmospheric activity on Jupiter such as the continued absence of the planet's South Equatorial Belt, the prominence of the Great Red Spot, and the appearance of dusky spots along bands. Don Parker's photo of the giant planet shows its appearance on February 4 (bottom). Additionally, high sunspot activity continued on the Sun's disk, as evidenced by Gordon Garcia's photo (below).







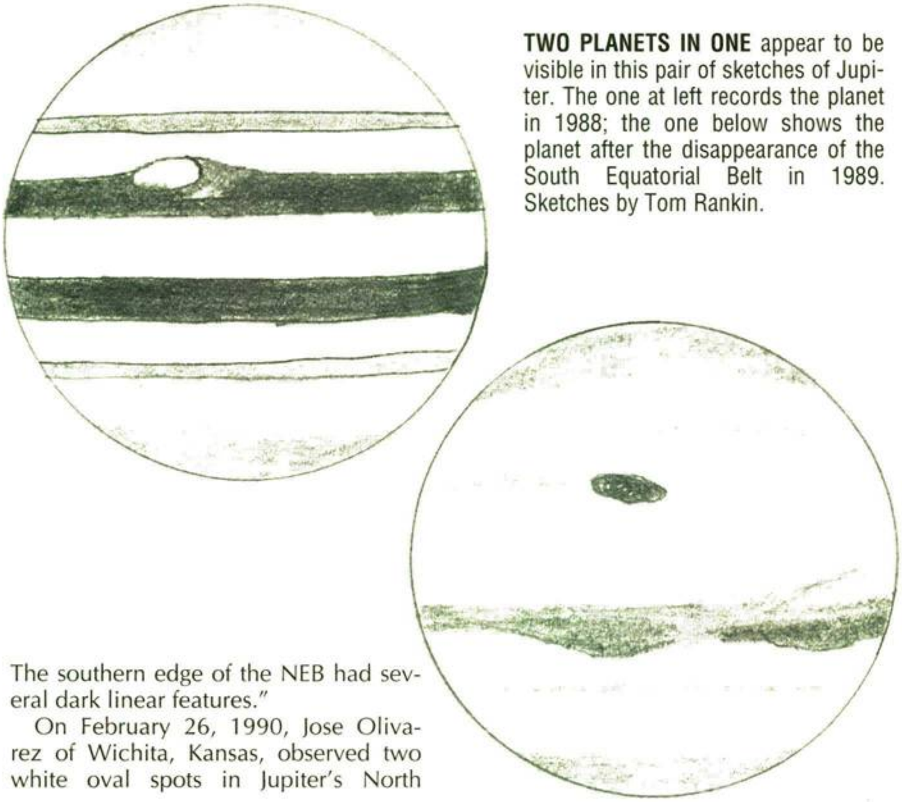


JUPITER'S REFASHIONED LOOK

Jupiter continued to show unpredictable changes in its cloud features throughout early 1990. The most noteworthy aspects were the continued invisibility of the planet's normally prominent South Equatorial Belt (SEB) and the continued slight darkening of the Great Red Spot, which had been relatively difficult to see for some years. Various smaller cloud features were observed in large numbers by the legion of amateur astronomers who monitor Jupiter whenever they can.

Fred W. Price of Buffalo, New York, has been checking Jupiter's features regularly with an 8-inch reflector since last summer. "Last December and February I spotted what may be traces of the SEB," said Price. "The Great Red Spot was a pale, orange-pink feature, isolated and surrounded by bright zone material. The equatorial region had a pale yellowish color and the planet's disk north of the North Equatorial Belt (NEB) was the usual ivory white color; the rest of the planet's disk, however, appeared to be a duller white color. The southern edge of the NEB had several dark linear features."

On February 26, 1990, Jose Olivarez of Wichita, Kansas, observed two white oval spots in Jupiter's North



TWO PLANETS IN ONE appear to be visible in this pair of sketches of Jupiter. The one at left records the planet in 1988; the one below shows the planet after the disappearance of the South Equatorial Belt in 1989. Sketches by Tom Rankin.

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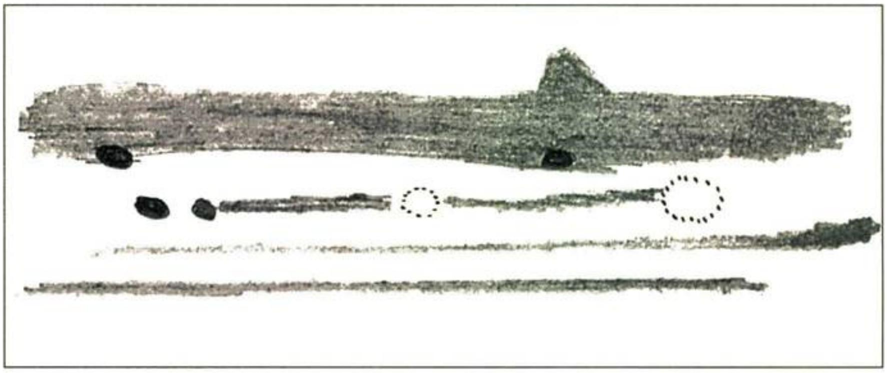
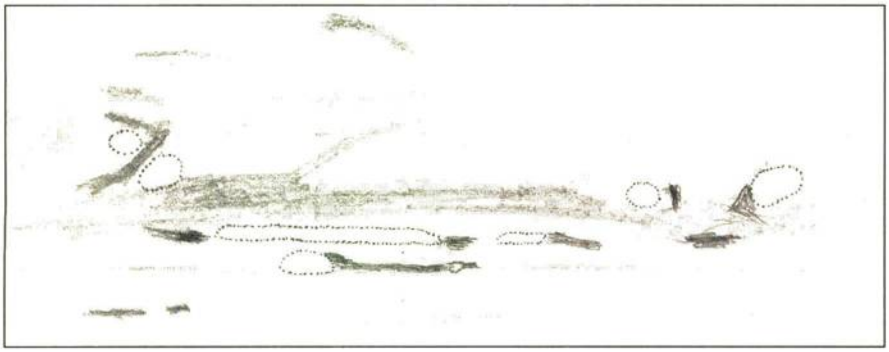
WHITE OVAL SPOTS are visible in this sketch of the North Equatorial Belt region of Jupiter made on February 26, 1990. Sketch by Jose Olivarez.



NUMEROUS BRIGHT AREAS appeared in Jupiter's North Equatorial Belt in mid-February. Visible in this sketch made with an 11-inch refractor are seven bright spots and elongated patches. Sketch by C. Benninghoven.



Temperate Belt, according to Philip W. Budine, Jupiter recorder for the Association of Lunar and Planetary Observers. Olivarez reported seeing "a white oval spot that transited at 0:30 UT on the 26th; a second spot was visible at the beginning of the observing period. However, the seeing turned worse before the second white spot reached the planet's central meridian. Contrast went to pieces and I was only able to estimate that the object transited at about 1:20 UT." — *David J. Eicher* ☐

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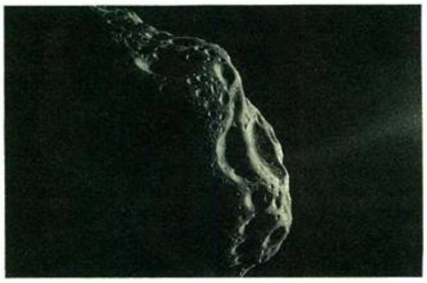
Book Reviews

A BIG BOOK ON MINOR PLANETS

Asteroids II, edited by Richard P. Binzel, Tom Gehrels, and Mildred Shapley Matthews, (University of Arizona Press, 1989), ISBN 0-8165-1123-3, hardcover, 1,258 pages, $50.00.

In October 1991 the first close up study of an asteroid will be made as the *Galileo* spacecraft, enroute to its December 1995 rendezvous with Jupiter, flies past asteroid 951 Gaspra. The spectral measurements and television images of this one asteroid will be used to test many hypotheses that astronomers have developed using information from Earth-based observations.

As is evident from this thick tome, the body of knowledge derived from Earth-based observing techniques is impressive. One hundred authorities have collaborated to produce fifty-one review papers on all aspects of asteroid research. Beginning with an overview by minor-planet expert Richard Binzel, the book is divided into five general sections. The first section outlines the observing techniques and measurements that have been employed to study asteroids. These include spectral observations, light variations, stellar occultations, and radar bounces. The second section discusses the structure and physical properties inferred from the measurements, including rotation rates, and attempts at classifying certain objects by their spectral characteristics or orbital parameters.



EROS IS A FAST-MOVING Earth approaching asteroid about 35 kilometers in length. Painting by Adolf Schaller.

The section on origins and evolution outlines our current understanding of how the asteroid belt came to be. (Jupiter's gravitational tugs would not let the asteroids form into a single planet between Mars and Jupiter). Is the current population of the asteroid belt really representative of the material from which the inner planets formed four and one half billion years ago? (The outer belt objects probably are, but those closer to the Sun have been melted.) Where are the parent asteroids for the most common meteorites, the so-called ordinary chondrites? (There are no obvious candidates in the main asteroid belt. Only the Earth-approaching asteroid 1682 Apollo has spectral characteristics similar to those of the ordinary chondrite meteorites, and Apollo is too small to be a sufficient source.) Are some asteroids actually inactive comets? (Probably.) Are some *active* comets? (The most distant asteroid known, 2060 Chiron, has recently shown a cometlike atmosphere, even though it spends most of its time between Saturn and Uranus.)

A section on space studies outlines, in two papers, the measurement possibilities of using the *Hubble Space Telescope* and future missions to asteroids. The final portion of the book tabulates such information as asteroid orbital parameters and discovery circumstances, as well as their magnitudes, spectral colors, reflectivity, variability, spin periods, and spin pole positions.

The book is nicely structured with uniform typeset pages and a comprehensive glossary and index. Though intended for university graduate students, much of the text is accessible to the layperson. For those wishing only a brief introduction to asteroids, Clifford Cunningham's *Introduction to Asteroids* (Willmann-Bell, 1988) is highly recommended. Those who wish to pursue the subject in more detail could do no better than this authoritative and well-written work. — *Donald K. Yeomans, Jet Propulsion Laboratory*

BOOKS RECEIVED

General Astronomy

The Greenwich Guide to Astronomy in Action and The Greenwich Guide to Stargazing by Carole Stott, The Greenwich Guide to the Planets and The Greenwich Guide to Stars, Galaxies, and Nebulae by Stuart Malin, (Cambridge University Press, 1990) ISBN 0-521-37774-9, 37775-7, 37776-5, and 37777-3, respectively, softcover, 96 pages each, $9.95 each.

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Each volume, however, stands on its own. The titles are self explanatory, except, perhaps, for *Astronomy in Action*, which details the methods and sophisticated instruments astronomers use to study the universe. The books measure 8 1/4" by 7 1/4" and are illustrated with color photos and diagrams.

The Night Sky: A Guide for the Young Astronomer by Dennis Mammana, (Running Press, 1990), ISBN 0-89471-764-2, softcover, 94 pages, $9.95.

The Night Sky is a good beginning for any child (or the child in you) with a budding interest in astronomy. Mammana presents tips on observing the Moon, planets, and constellations with just the right amount of science to explain what is being seen. The book also includes chapters on meteor showers, distances in space, and using small telescopes.

Pronunciations of star names, constellations, and terms are prevalent throughout the book, as are suggestions for astronomy experiments and activities. Seasonal sky maps feature the bright constellations and stars, along with directional arrows that help the observer navigate through the sky.

The Moon map, unfortunately, did not reproduce well enough to clearly show the dominant lunar features. The publisher should consider creating a new lunar map for future editions.

Space Exploration

The Illustrated Encyclopedia of Space Technology, revised edition, by Kenneth Gatland, (Random House, 1990), ISBN 0-517-57427-6, hardcover, 306 pages, $29.95.

Eight years after its original publication, Gatland has published this impressive revised edition, reporting on the emerging space powers of China, Japan, and Europe as well as the notable advances made by the Soviet space program. The book is packed with historical and technical information in a very readable style. Measurements and values are given in both English and metric units. Color photos and diagrams abound.

Especially interesting are the exploded color views of manned spacecraft (the *Vostok* and *Mercury* capsules, for example) as well as orbiting scientific instruments like the *Hubble Space Telescope* and the *Infrared Astronomical Satellite*. The "Space Diary" at the end of the book takes the reader from 360 B.C. to the Neptune flyby of *Voyager 2*. A glossary is provided. ☐

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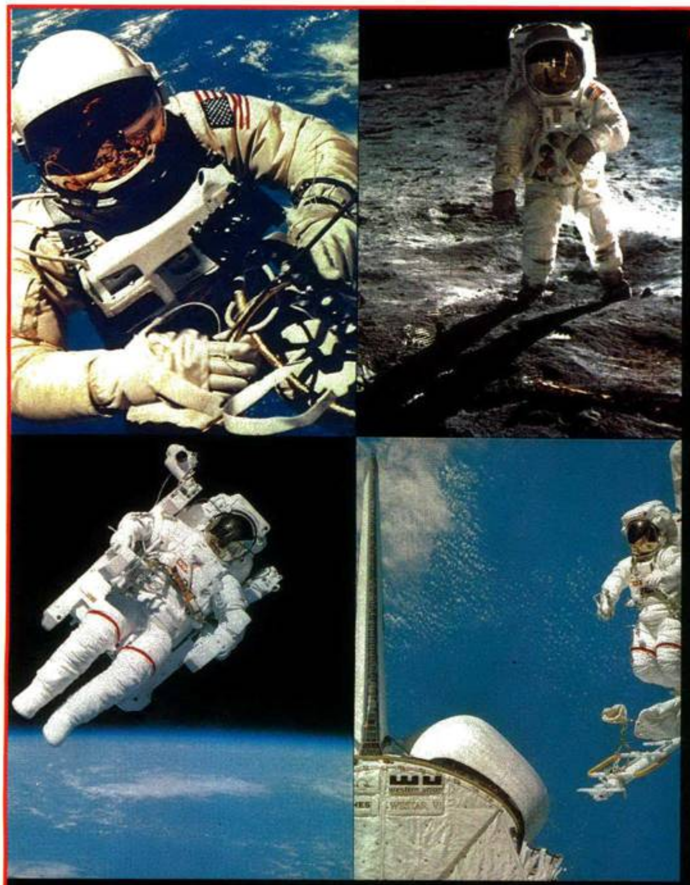

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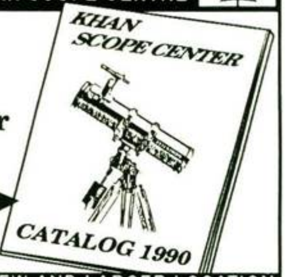

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Astronomy Product Reviews

SPOTTING SATELLITES MADE EASIER

Space Birds, (Astronomical Data Service, P.O. Box 26180, Colorado Springs, CO 80936; (303) 597-4068); for IBM PCs and compatibles; $40.00.

Space Birds is the first software I've seen for figuring the visibility and path of near-Earth satellites. This it does quite well, but the program takes a bit of preparation before you can get meaningful results.

First, you need to get on NASA's mailing list for orbital elements updates. A form letter and envelope for this are provided with *Space Birds*. Next you create a location file containing the geographical coordinates of your viewing site. You get this information from geological survey maps at your local library. You create the file with PC-Write, a general purpose text editor supplied with *Space Birds*.

NASA will send you the orbital elements for 20 operating satellites and a packet of related information. Every few days thereafter, you will receive updated orbital data for these satellites. From time to time NASA will add special interest satellites to your list.

With the NASA data in hand you create a file of orbital elements for the satellites you want to observe. You also prepare a file listing the dates you want to observe on and other observing criteria. For example, you can specify that coordinates be listed only for when the satellites are visible. Or if you want to pick up weather image transmissions with a satellite dish, you could request printouts of the satellites of interest.

After running the program you end up with a disk full of dates, coordinates, local time, Moon phase, and the Moon's position relative to the satellite. With the computed data you hand plot the satellite paths onto photocopies of a polar star map included in the instruction manual and you're ready to go outside and watch the "birds" fly by.

The file creation sounds like a pain, but it's really not difficult. Preparing the observer's location file is done only once. The satellite files you update as needed or you make new ones for different satellites or for new runs. This is probably the single most onerous part, but because the orbits of near-Earth satellites are constantly changing, last week's elements aren't much good.

To make file set-up easier, sample files are included with *Space Birds*. You just copy them into new file names of your choosing and overtype the existing data with the new numbers. It is very important that all the numbers be placed in exactly the right locations, spaces and all. Misplaced data will result either in the program's rejecting your file or giving you cockeyed plotting data. (In fact, most data errors cause the program to bomb.)

Space Birds saves the satellite observer a lot of work in preparing for viewing sessions. If that's your interest, this is a helpful program. — *Jim Bailey*

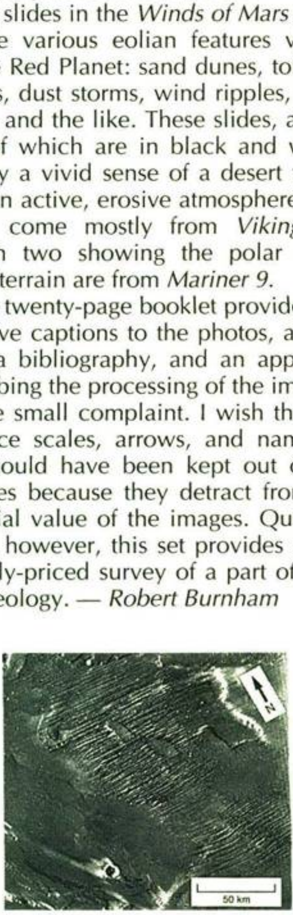
SLIDE SET

The Winds of Mars, (Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058, (713) 486-2139), 30 slides plus booklet, $15.00.

The slides in the *Winds of Mars* set illustrate various eolian features visible on the Red Planet: sand dunes, tornado streaks, dust storms, wind ripples, wind scour, and the like. These slides, all but four of which are in black and white, convey a vivid sense of a desert world with an active, erosive atmosphere. The slides come mostly from *Viking*, although two showing the polar laminated terrain are from *Mariner 9*.

The twenty-page booklet provides descriptive captions to the photos, a glossary, a bibliography, and an appendix describing the processing of the images.

One small complaint. I wish that the distance scales, arrows, and name labels could have been kept out of the pictures because they detract from the pictorial value of the images. Quibbles aside, however, this set provides a reasonably-priced survey of a part of Martian geology. — *Robert Burnham* ☐



MARTIAN YARDANGS are straight grooves gouged out by the wind. This photo from the *Winds of Mars* slide set shows a field of them that lies south of Olympus Mons.

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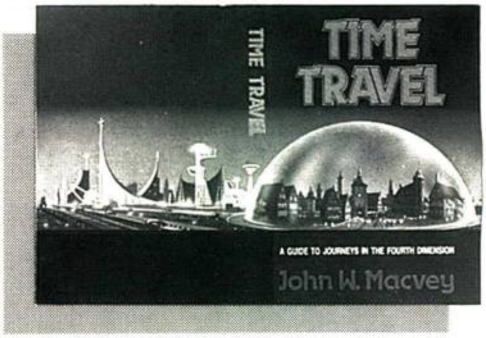

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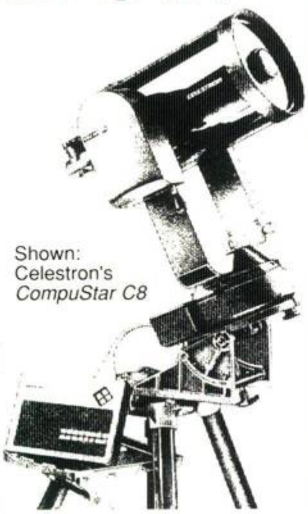

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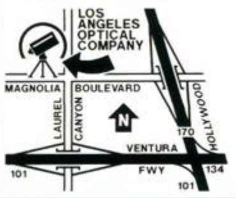

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- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, date, sidereal time, etc.
- 9V Battery lasts many nights.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision high resolution digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2080, Meade 2120 *(Specify)*	**$498**
For Celestron C-8, C-11 *(Specify)*	**$498**
For Coulter Odyssey 8", 10", 13", 17½"	**$498**
For any alt-azimuth (Dobsonian) scope	**$498**
For Celestron C-14 (rewire dec. motor)	**$575**
SKY VECTOR KIT (for skilled ATM's)	**$459**

Reference catalogues (1000's of objects)

Burnham's *Celestial Handbook*, I, II, III	**$36.85**
Revised New General Catalogue (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II	**$29.95**

OFF ON
DIM
1735+273
RA
DEC
MODE
STAR
UP
DOWN
Sky Vector II™
COMPUTER SETTING CIRCLES
LUMICON®

LUMICON SKY VECTOR II™ Computer with 1000 object memory, digital readout of coordinates, easy-to-use controls.

Please specify telescope type:

LUMICON SKY VECTOR II™ for Meade 2080, Meade 2120 *(Please specify)*	**$589**
For Celestron C-8, C-11 *(Specify)*	**$589**
For Celestron C-14 (rewire dec. motor)	**$665**
For Coulter Odyssey 8",10",13"17½"	**$589**
For any alt-azimuth (Dobsonian) scope	**$589**

LUMICON NGC SKY VECTOR™. Has same features as the LUMICON SKY VECTOR II™ but has all 7730 revised NGC objects in memory. However, it does not have the best IC and non-NGC objects.

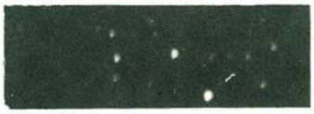
NGC SKY VECTOR™ for C-8, C-11	**$750**
For Meade 2080, Meade 2120	**$750**
For Coulter Odyssey 8",10",13",17½"	**$750**
For C-14 (rewire dec. motor)	**$825**

The **LUMICON SKY VECTOR II**™ has all the features of the regular SKY VECTOR, but has 1000 of the best deep-sky objects in memory along with their coordinates, size, magnitude, and other descriptive data. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

LUMICON SKY VECTOR II FEATURES:

- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory without power.
- 430 galaxies, groups & clusters
- 137 best open star clusters
- 133 best planetary nebulae
- 59 emission & reflection nebulae
- 84 best gobular star clusters
- 149 best colored & multiple stars
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1000 objects in memory

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON ACCESSORIES

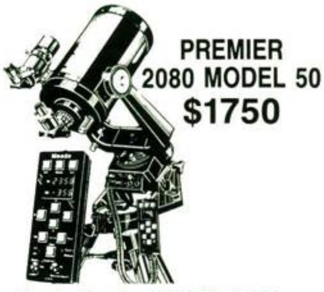
NEW PREMIER SERIES TELESCOPES

All Meade Premier Series telescopes **include** multi-coated enhanced optics (MCOG) and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has an 6X30 finderscope and the 10" has an 8X50 finderscope.

2080 Model 30, 8" f/10	**$1450**
2080 Model 36, 8" f/6	**$1650**
2120 Model 30, 10" f/10	**$1850**
2120 Model 36, 10" f/6	**$2298**

Options Enhance Performance

Super Wedge for 10"	**Add $295**
Dual-axis handbox controller	**Add $119**
Declination motor	**Add $109**
Digital setting circle	**Add $399**
2" Star diagonal	**Add $179**
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	**Add $225**
LUMICON Giant Easy-Guider (for #30) *(Specify camera)*	**Add $395**
LUMICON Giant Easy-Guider (for #36) *(Specify camera)*	**Add $295**



Meade Premier 2080 Model 50

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2045D 4" f/10 w/motor drive	**$695**
2080 Original 8" f/10 w/tripod	**$999**
2080 Original w/tripod, MCOG	**$1058**
2080 Model 50, 8" f/10	**$1750**
2120 Model 50, 10" f/10	**$2195**
2120 Model 50H, 10" f/10 w/Super Wedge	**$2395**
2080 Model 56, 8" f/6.3	**$1950**
2120 Model 56, 10" f/6.3	**$2395**
2120 Model 56H, 10" f/6.3 w/Super Wedge	**$2595**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$898**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

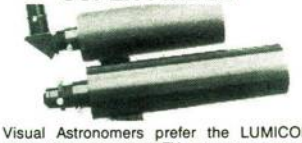
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser 1½" high	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$129.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra. The

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER*	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$159**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

LUMICON means INNOVATION

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- 2X higher resolution encoders
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

- **No need** to enter latitude, longitude, sidereal time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

Sky Vector ™
ON OFF
2137+490
DIM
RA
DEC
MODE
STAR
LUMICON

LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a breakthrough in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11, *(Specify)*	**$498**
For Celestron-14 .. **$575.** For any alt-azimuth (Dobsonian) telescope	**$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)*	**$498**
SKY VECTOR KIT. You must supply adapting hardware. For skilled ATM's only	**$459**

Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects	**$29.95**

NEW FROM LUMICON

NGC SKY VECTOR™ $750

- Advanced version of the LUMICON SKY VECTOR™ with over 8000 object deep-sky memory
- All 7730 revised NGC objects
- All 110 Messier objects
- 365 double & multiple stars
- 25 user defined objects, comets, etc.
- Helps achieve perfect polar alignment (benefits photographers, not needed for viewing)
- For alt-azimuth, equatorial, fork mounts
- 2X higher resolution encoders
- Identifies unknown objects
- Directs telescopes to desired objects by providing real-time angular distance to object
- Provides size, magnitude, coordinates, and visual description of all 8000 objects in memory

PLEASE SPECIFY TELESCOPE TYPE

LUMICON NGC SKY VECTOR™ for Meade 2080/2120	**$750**
NGC SKY VECTOR™ for C-8, C-11	**$750**
NGC SKY VECTOR™ for Celestron-14	**$825**
NGC SKY VECTOR™ for Coulter Odyssey 8, 10, 13, 17½"	**$750**
LUMICON NGC SKY VECTOR™ Kit, you supply hardware	**$709**
LUMICON NGC SKY VECTOR™ Kit for equatorial mounts	**$795**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼'' circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

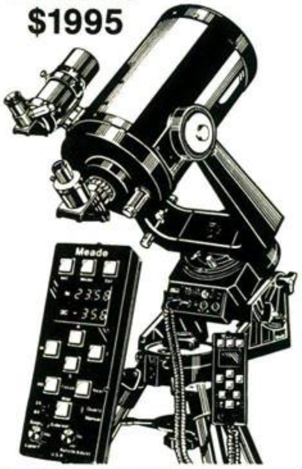
LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON ACCESSORIES

2080/LX6 8'' f/6 .. $1995
2120/LX6 10'' f/6 . $2499

Digital readout system for 2080/2120/LX6	**$399**
8200 object memory CAT computer	**$999**

NEW 2080/LX6 $1995



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2080 Original w/tripod, MCOG	**$1089**
2080 Original 8" f/10 w/tripod	**$999**
2080/LX3, 8" f/10 w/MCOG	**$1450**
2080/LX5, 8" f/10 w/MCOG	**$1650**
2120/LX5, 10" f/10 w/MCOG	**$2095**
2120/LX3, 10" f/10 w/MCOG	**$1895**
2045D 4" f/10 w/motor drive	**$695**
#39 declination motor for LX5	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser	**$129.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

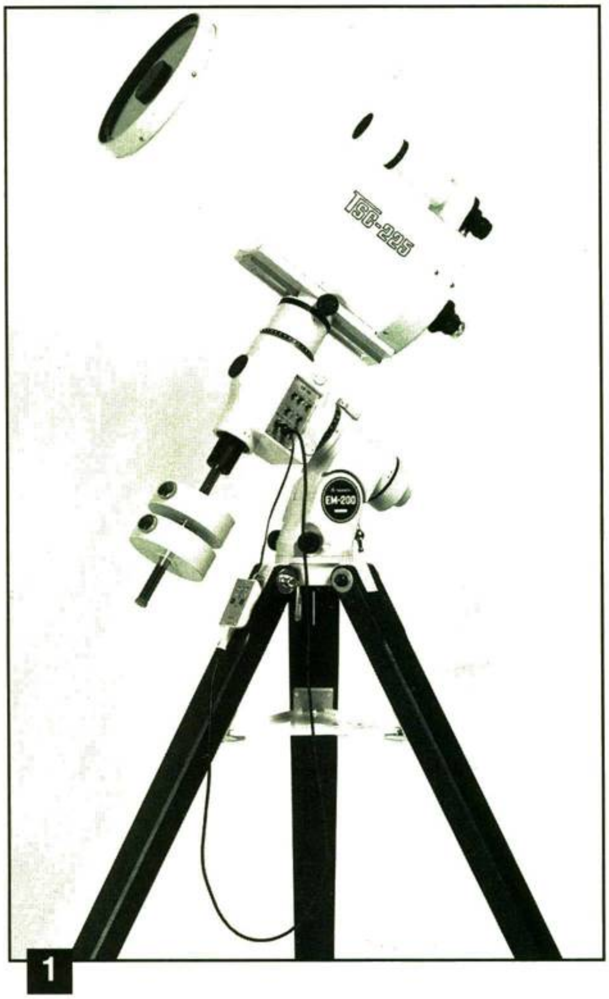
1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
1¼" Deluxe right-angle Super-Finder*	**$279**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$159**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2'' ADAPTERS MEADE, CELESTRON TELESCOPES

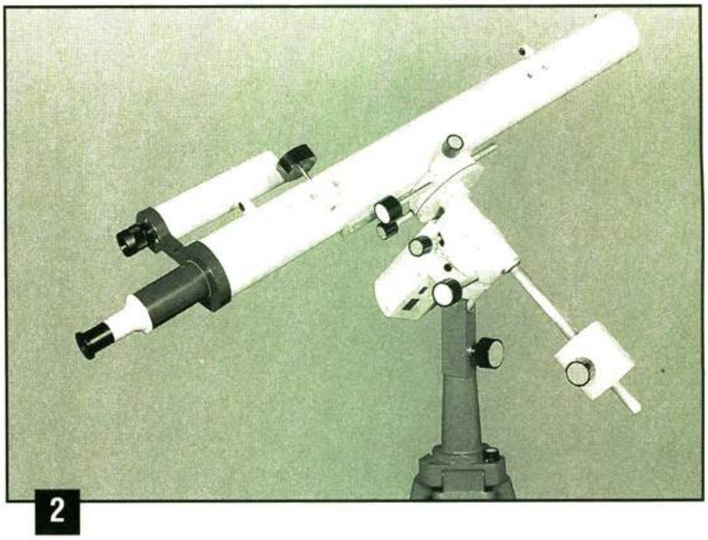
These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

New Astronomy Products


TSC-225
EM-200

1



2

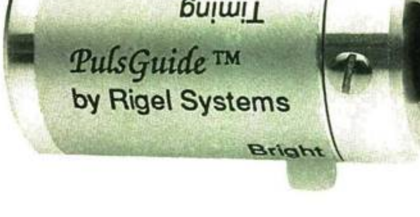
3

4

Starlite TM
by RIGEL SYSTEMS

5

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.


On Off
Timing
PulsGuide TM
by Rigel Systems
Bright

6

1 Takahashi TSC-225 Schmidt-Cassegrain

A new 225mm (8.9-inch) aperture Schmidt-Cassegrain telescope is available from Takahashi. Features include hand-figured optics, fifteen internal tube baffles, multi-layer enhanced aluminum mirror coatings, a 2-inch visual back, rear cell ventilation ports, an optional cooling fan, and a straight-through finder. The mount is the Takahashi EM-200 with a stated accuracy of ±5 arcseconds, wooden tripod, polar alignment scope, and 2x and 16x speed override. Available from Texas Nautical Repair and select dealers.

Texas Nautical Repair, 2129 Westheimer, Houston, TX 77098; (713) 529-3551. System price: $5,489.00; tube only: $2,750.00, mount only: $2,980.00.

2 aus Jena Telescopes

VERNONscope now operates the exclusive U.S. dealership for the German aus Jena line of astronomical telescopes. Manufactured in East Germany, the aus Jena line includes 63mm and 100mm refractors and a 180mm Maksutov, as well as eyepieces, refractor objective lenses, and a range of accessories. Telescopes and mountings feature heavy-duty construction. Write for brochures and price lists.

VERNONscope and Co., #5 Ithaca Road, Candor, NY 13743; (607) 659-7000.

3 aus Jena Binoculars

Two new German aus Jena binoculars are available in the United States: the Notarem 10x40BGA and the 8x32BGA. Both are rubber-armored roof-prism designs with central internal focusing. Aus Jena binoculars are available through dealers in the United States or directly from Europtik Ltd. Write for lists of dealers and prices for the entire aus Jena line of binoculars.

Europtik Ltd., P.O. Box 319, Dunmore, PA 18512; (717) 347-6049, FAX (717) 969-4330. 10x40 model: $590.00; 8x32 model: $550.00.

4 Parks Deluxe Giant Binoculars

The new Parks ZCF Deluxe series is available in three sizes: 11x80, 15x80, and 20x80. All use prisms with BPG-2 glass, claimed to be superior over traditional BaK-4 prisms with improved light transmission and no vignetting of the exit pupil. All feature multi-coatings, a central bridge support near the objective lens, soft rubber eye cups, and built-in lens shades. Each model is rubber-armor coated for shock and water resistance and comes with a carrying case, lens caps, and tripod adapter. Includes lifetime guarantee. Available through dealers or directly from Parks.

Parks Optical, 270 Easy Street, Simi Valley, CA 93065; (805) 522-6722, outside California (800) 44-PARKS. $399.00 (factory direct price) plus $12.00 shipping in continental United States.

5 Starlite

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Rigel Systems, 28006 Ridgebrook, Rancho Palos Verdes, CA 90274; (213) 544-6574. $24.95.

6 PulsGuide

Designed to fit most popular guiding eyepieces, *PulsGuide* is an LED light source with user selectable pulse rate, duration, and brightness. According to the manufacturer, pulsing the illuminated reticle reduces eye fatigue and improves visibility of faint guide stars. A battery life of up to 70 hours from one 3-volt lithium cell is promised. Available with either screw-in or set-screw adapter to attach to guiding eyepiece (specify type when ordering). Available from Spectra Astro-Systems and other dealers.

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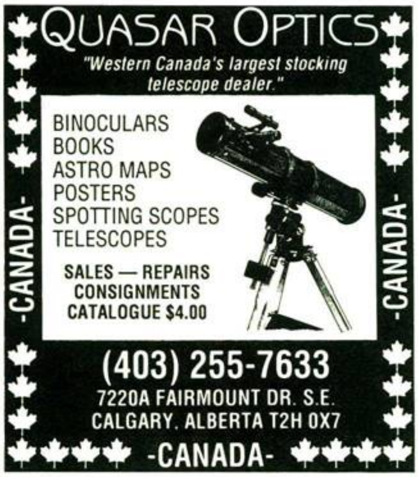
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Meetings and Events

July 13-15
Symposium on Automated Telescopes and Global Networking, Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 13-18
Astronomical Society of the Pacific Annual Meeting, Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 14
Public Star Party, Charles Hayden Planetarium, Boston, Massachusetts. Sponsored by the Amateur Telescope Makers of Boston and the Astronomical Society of the Pacific.

July 14-15
The Universe in the Classroom, Boston University, Boston, Massachusetts. Contact: Workshop Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 20-21
Astronomical League Northwest Regional Convention, Ellensburg, Washington. Contact: Tom Jenkins, South 3312 Pittsburgh, Spokane, WA 99203. Phone: (509) 838-1381.

July 20-22
Front Range Astronomical Super-Cluster Star Party, Badger Flats, Colorado. Sponsored by the Colorado Springs and Denver Astronomical Societies. Contact: Robert Stencel, University of Colorado, Campus Box 391, Boulder, CO 80309. Phone: (303) 492-4050.

July 20-22
20th Annual NFCAAA Summer Seminar, Darling Hill Observatory, Vesper, New York. Sponsored by the Syracuse Astronomical Society, Inc. Contact: John Rusho, Box 19, RD 7, Fulton, NY 13069. Phone: (315) 592-5866 (evenings and weekends).

July 24-28
First European Meeting of the American Association of Variable Star Observers, Brussels, Belgium. Contact: Janet A. Mattei, AAVSO, 25 Birch Street, Cambridge, MA 02138.

July 27-28
Stellafane, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

July 31-August 4
Astronomical League National Convention, Washington University, St. Louis, Missouri. Sponsored by the St. Louis Astronomical Society. Contact: Steve Best, 6943 Amherst Avenue, University City, MO 63130; or Wayne Clark, 310 Calvert Avenue, Webster Groves, MO 63119.

August 17-18
Starfest '90, Riverplace Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5. Phone: (416) 761-1798.

August 17-19
The Conjunction, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Richard Sanderson, P.O. Box 54, Monson, MA 01057.

August 17-19
Front Range Astronomical SuperCluster Star Party, Fox Park, Wyoming. Sponsored by the Cheyenne and Denver Astronomical Societies. Contact: Robert Stencel, University of Colorado, Campus Box 391, Boulder, CO 80309. Phone: (303) 492-4050.

August 17-19
Northwoods Starfest, Eau Claire Youth Camp, Beaver Creek Reserve, Wisconsin. Sponsored by the Chippewa Falls Astronomical Society. Contact: Kevin Litten, 921 West Willow, Chippewa Falls, WI 54729. Phone: (715) 726-2382.

August 17-19
2nd Annual Southern Minnesota Sky Show, near New Ulm, Minnesota. Sponsored by the Minnesota Valley Amateur Astronomers. Contact: Minnesota Valley Amateur Astronomers, Route 4, Box 15A, New Ulm, MN 56073.

August 17-20
Nova East '90 Star Party, Fundy National Park, New Brunswick. Contact: Halifax Centre of the R.A.S.C., 1747 Summer Street, Halifax, Nova Scotia, Canada B3H 3A6.

August 17-24
Meteor '90 Convention, Ráktanya, Hungary. Sponsored by the Hungarian Astronomical Association. Contact:

Hungarian Astronomical Association, 1253 Budapest, P.O. Box 36, Hungary.

August 18
Prairie Astronomy Club Picnic and Star Party, Hyde Observatory, Holmes Park, Lincoln, Nebraska. Contact: Prairie Astronomy Club, P.O. Box 80553, Lincoln, NE 68501.

August 18-20
3rd Annual Oregon Star Party, Steens Mountain, Frenchglen, Oregon. Sponsored by the Rose City Astronomers of Portland. Contact: Chuck Dethloff, 15111 NW Oakmont Loop, Beaverton, OR 97006. Phone: (503) 629-2145, or Dale Fenske (503) 256-1840.

August 22-26
Mount Kobau Star Party, near Osoyoos, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

August 24-26
4th Annual Astronomy Rendezvous and Conference, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers. Contact: Twin City Amateur Astronomers, P.O Box 755, Normal, IL 61761.

September 8
StarConn '90, Wesleyan University, Middletown, Connecticut. Sponsored by the Astronomical Society of Greater Hartford. Contact: Suzanne Marinan, 367 Suger Hill Road, Tolland, CT 06084-2116.

September 14-16
Astrofest '90, Camp Shaw-Waw-Nas-See, Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477.

September 18-23
Okie-Tex Star Party, Lake Murray State Lodge, near Ardmore, Oklahoma. Sponsored by the Oklahoma City Astronomy Club. Contact: Okie-Tex Star Party, c/o Beryl Cadle, 6616 NW 20th, Bethany, OK 73008. ☐

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When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information.

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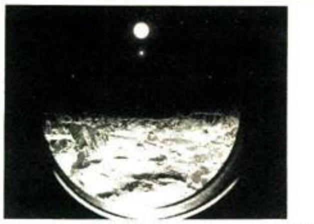

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Readings and Resources

Venus Volcanos (page 42)

Venus by Eric Burgess, (Columbia University Press, 1985). A readable survey written for the interested layman.

Venus, edited by Donald M. Hunten and others, (University of Arizona Press, 1983). A collection of technical papers with several review articles written at a level laymen can understand.

Planetary Portrait (page 62)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). A good introductory book on astrophotography covering all techniques.

The Manual of Advanced Celestial Photography by Brad Wallis and Robert Provin, (Cambridge University Press, 1988). As the title suggests, lots of information on advanced techniques, plus detailed advice from two experienced astrophotographers.

Journey into Darkness (page 68)

"United States Naval Observatory Circular No. 174: Total Solar Eclipse of 11 July 1991," (Eclipse Circulars, U.S. Naval Observatory, Washington, DC 20392). A 66-page booklet that tells you everything you want to know about next year's eclipse. Includes detailed large-scale maps of the eclipse path. Single copies available free.

Scutum Star Cloud (page 76)

Deep Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep Sky,* (Enslow Publishers, 1989). An introductory observing guide featuring hundreds of objects, including all the major sights in the Scutum region. ☐

CREDITS

Cover: Ken Hilgendorf; *page 4:* Hans-Emil Schuster and Guido Pizarro/European Southern Observatory; *page 22:* NASA/Goddard Space Flight Center; *page 23:* Ed Barker; *page 25:* NASA/U.S. Geological Survey; *pages 42-43:* painting by Michael Carroll; *page 44:* diagrams by Patti L. Keipe, based on data provided by the author; *page 45:* Venus map courtesy U.S. Geological Survey/MIT, lightning data provided by the author; *page 46:* diagrams by Patti L. Keipe, based on a model developed by Roger Phillips and Michael Malin; *pages 48-49:* Harvard College Observatory; *page 50, top and bottom right:* Harvard College Observatory; *page 50, bottom left:* Katherine Haramundanis; *page 51:* Harvard College Observatory; *page 54:* Ernest Piini (f/22 telephoto lens, Kodachrome II film, 1/60-second exposure); map courtesy Fred Espenak, NASA/Goddard Space Flight Center; *page 57:* map courtesy U.S. Naval Observatory; *page 62:* Mark Coco (16-inch Cassegrain, Ektachrome 400 film, 13-second exposure); *page 63:* Mars photos by Harold Moore, *from top to bottom:* (September 30, 1988, October 9, 1988, October 17, 1988, October 24, 1988); *page 64, top:* Mark Coco (8-inch f/10 SCT with 9mm eyepiece projection, Ektachrome 400 film, 1/2-second exposure); *second from top:* Bill Braithwaite (1/2-second exposure); *third from top:* Steve Reed (8-inch SCT at f/138, High Speed Ektachrome film, 1-1/2-second exposure); *bottom:* David Lee (8-inch SCT at f/140, Fujichrome 400 film, 4-second exposure); *page 65, top left:* Jean Dragesco (14-inch f/11 SCT, Ektachrome 200 film, March 16, 1981); *page 65, top middle:* Mark Coco (16-inch Cassegrain with 10mm eyepiece projection, Fujichrome 1600D film, 1-second exposure, August 9, 1986); *page 65, top right:* Gregory Terrance (16-inch reflector at f/63, Ektachrome 200 film, January 5, 1990); *page 63, center:* Mark Payne-Gill (12.5-inch reflector, Fujichrome 100D film, 1/60-second exposure); *page 63, bottom:* Mark Payne-Gill (300mm telephoto lens, Fujichrome 50D film, 1/125-second exposure); *page 66, top left and top right:* Mark Coco (8-inch SCT at f/62, Ektachrome 400 film, 1/60-second exposure); *page 66, center:* Mark Coco (8-inch f/10 SCT, Fujichrome 1600D film at ISO 400); *page 67, top:* Scott Rosen (8-inch SCT at f/30, Fujichrome 400 film, 2-second exposure); *page 67, bottom:* Rick Albrecht (14-inch SCT at f/70, Ektachrome 400 film at ISO 800, 8-second exposure); *page 69:* Eric Wahlin (February 26, 1979); *page 70:* Carter Roberts (March 19, 1988, Indonesia); *page 71:* Joel Harris (December 1988); *page 72:* Jacques Guertin; *page 73:* GOES satellite image taken 18:45 UTC, July 28, 1988, courtesy Jay Anderson; *page 74:* Paul Deans (Canberra cruise, 1973); *page 76:* George R. Viscome (14.5-inch f/6 reflector, Fujichrome 400 film with cold camera, 12-minute exposure); *page 77:* Ronald Royer; *page 78, top:* Martin C. Germano (8-inch f/5 reflector, hypersensitized Tech Pan film, 35-minute exposure); *page 78, bottom:* Lee C. Coombs (10-inch f/5 reflector, 103a-O film, 5-minute exposure); *page 83, top:* Scott McGurk (16mm f/4 fisheye lens, Fujichrome 1600 film, 3-minute exposure, March 20, 1990); *page 83, bottom:* Bill Tetley (50mm f/2.8 lens, Konica 100 film, 40-second exposure); *page 84, top left:* Chris Schur (14-inch f/5 reflector, Ektar 1000 film, 10-minute exposure); *page 84, bottom left:* Jeffrey L. Jones (8-inch f/10 SCT, hypersensitized Tech Pan film, 15-minute exposure); *page 84, top right:* Gordon Garcia (8-inch f/10 SCT at f/32, Tech Pan film, 1/60-second exposure with a Daystar H-alpha filter); *page 84, bottom right:* Donald C. Parker (16-inch f/6 reflector at f/93, Fujichrome 100 film, 4-second exposure, February 4, 1990); *page 85:* George E. Fowler (14-inch f/11 SCT coupled to a STAR I CCD camera, 2-minute exposure, image processed using a Macintosh II computer, printed on a Tektronix thermal color printer); *page 86:* sketches by Tom Rankin (8-inch f/5 reflector at 120x in 1988, December 18, 1989); *page 87, top:* sketch by Jose Olivarez (12.5-inch reflector at 154x, February 26, 1990); *page 87, bottom:* sketch by C. Benninghoven (11.5-inch f/15 refractor at 200x and 292x, February 19, 1990).

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ANNOUNCEMENT — Escambia Amateur Astronomers Association, Pensacola, FL meets first Friday of each month at Owens Planetarium, Pensacola Junior College's Main Campus, 1000 College Blvd., 7 p.m. Monthly program and constellation presented prior to business meeting. Public invited. Contact Margret Hildreth, Escambia Amateur Astronomers, 4100 Lillian Highway, Pensacola, FL. Phone (904) 456-0078.

ANNOUNCEMENT — The Bucks-Mont Astronomical Association meets the first Wednesday of each month in the farm house at Tamanend Park, Second Street Pike, Southampton, PA. Phone Brad Miller, (215) 968-2521.

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WANTED — Thirty-year-old beginner seeks correspondence with others interested in astronomy, and telecope making. I promise to reply to all letters. Contact Deirdre P. Thompson, 51 Rothbury Terrace, Newcastle on Tyne, NE6 5XJ, United Kingdom.

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